Supplementary Information

The Genetic History of Northern Europe

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Supplementary Information Section 1. Archeological context and sample description.

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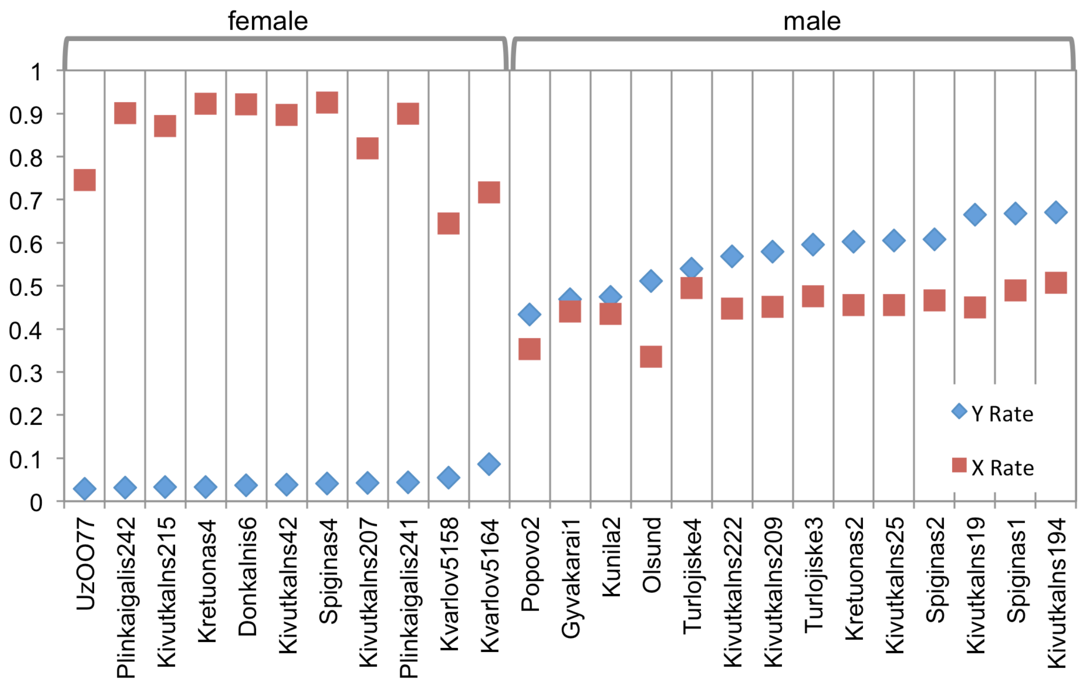
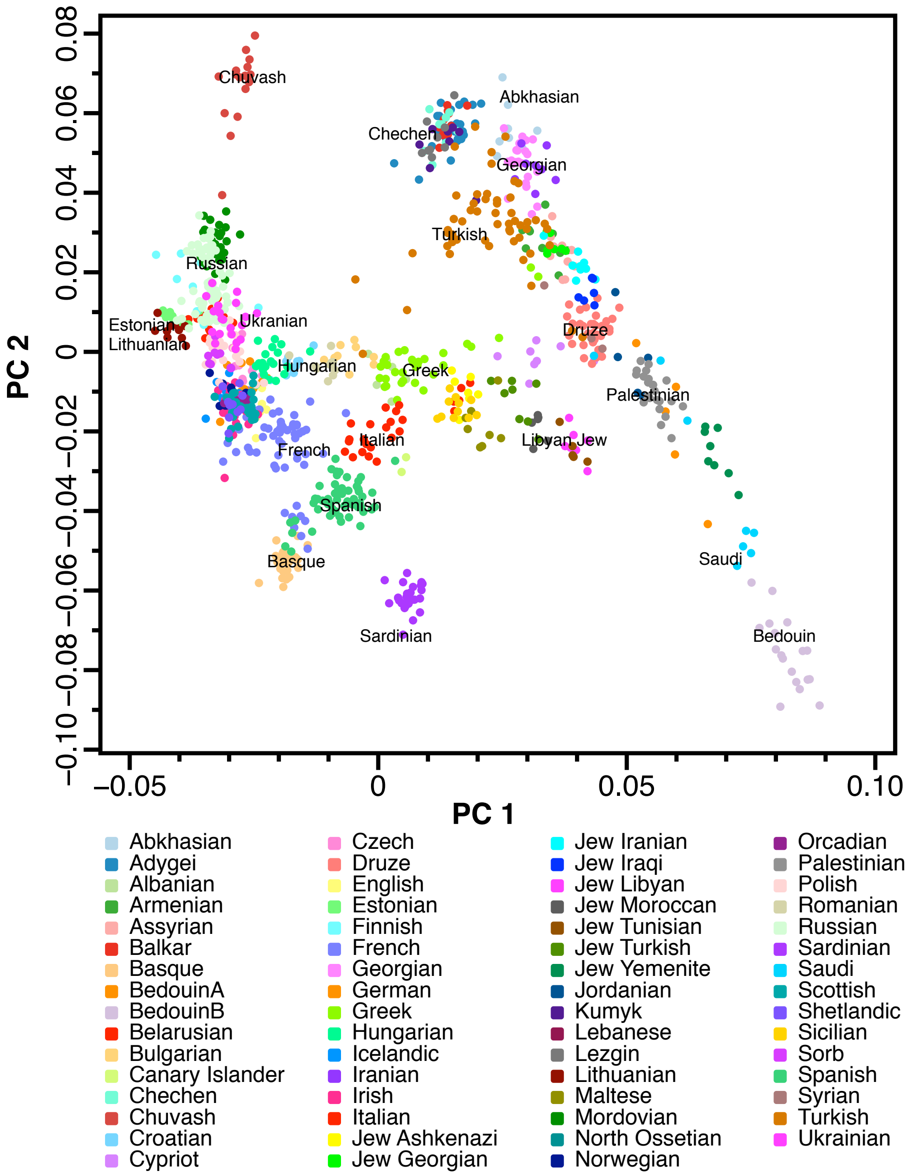


Supplementary Information Figure S1. Sex determination using the X rate/Y rate method. The Y rate shows greater usefulness in distinguishing male from female samples.



Supplementary Information Figure S2. PCA analysis on modern West Eurasian populations. Showing population labels for 1007 modern individuals used to construct the PCA in Fig. 2a.

Supplementary Information Table S1. Negative results for admixture f_3(Source A, Source B; Target). All combinations of ancient populations were tested as sources for a Target ancient Scandinavian or eastern Baltic population under study. The twelve most negative hits are shown for tests with more negative results.

Target	Source A	Source B	f_3-value	Std. error	Z
Baltic LNBA	Anatolia_N	EHG	-0.010247	0.000922	-11.118
	CHG	Kunda	-0.014097	0.001634	-8.626
	EHG	Europe_EN_Starcevo	-0.012102	0.001886	-6.417
	Iran_LN	Kunda	-0.011527	0.00209	-5.516
	Iran_N	Kunda	-0.011431	0.001751	-6.529
	Iran_HotuIIIb	Kunda	-0.011009	0.002983	-3.69
	CHG	Narva	-0.010958	0.001184	-9.254
	CHG	SHG	-0.010766	0.001091	-9.872
	Iran_N	Narva	-0.010741	0.001294	-8.302
	EHG	Levant_N	-0.010656	0.001129	-9.44
	Iran_HotuIIIb	WHG	-0.010646	0.002052	-5.187
	Iran_LN	Narva	-0.010593	0.001437	-7.371
Baltic BA	CHG	Kunda	-0.008067	0.001639	-4.921
	Iran_LN	Kunda	-0.006938	0.002022	-3.43
	Iran_HotuIIIb	WHG	-0.006711	0.001885	-3.559
	Iran_ChL	Narva	-0.006586	0.000833	-7.903
	Iran_N	Narva	-0.006396	0.001167	-5.481
	Iran_LN	Narva	-0.006297	0.00127	-4.957
	Kunda	Levant_BA	-0.00628	0.001344	-4.673
	Iran_N	Kunda	-0.006278	0.00169	-3.714
	Iran_LN	WHG	-0.006238	0.001368	-4.56
	Iran_ChL	Kunda	-0.006139	0.001259	-4.875
	Iran_ChL	WHG	-0.006012	0.000931	-6.457
	Levant_BA	Switzerland_HG	-0.005562	0.001325	-4.198
MN TRB	Levant_N	Switzerland_HG	-0.019363	0.005397	-3.588
	Anatolia_N	Switzerland_HG	-0.013243	0.004	-3.311
	Europe_EN_LBK	Switzerland_HG	-0.012758	0.004164	-3.064
	Anatolia_N	WHG	-0.011853	0.003496	-3.39
Scandinavia LNBA	Anatolia_N	EHG	-0.010921	0.000974	-11.209
	Anatolia_ChL	Switzerland_HG	-0.013443	0.002069	-6.496
	Iran_HotuIIIb	WHG	-0.013133	0.002271	-5.784
	Levant_BA	Switzerland_HG	-0.012884	0.001444	-8.922
	Iran_ChL	Switzerland_HG	-0.012674	0.001331	-9.519
	Iran_LN	Switzerland_HG	-0.012662	0.001914	-6.614
	Armenia_EBA	Switzerland_HG	-0.012406	0.001357	-9.142
	Iran_N	WHG	-0.012274	0.00132	-9.296
	EHG	Europe_EN_Starcevo	-0.012095	0.002158	-5.605
	Iran_ChL	WHG	-0.011965	0.001078	-11.095
	CHG	WHG	-0.011939	0.001237	-9.652
	Levant_N	Switzerland_HG	-0.011889	0.001487	-7.994

Supplementary Information Table S2. Significantly positive results for *D*(*Ancient Eastern Baltic population*, *A*; *X*, Mbuti). *A* is a geographically or chronologically proximate population and *X* is every other ancient population. This test shows if *a modern Baltic population* shares significantly more alleles with *X* than Baltic_BA does with *X* when Z>3. The thirty tests with highest significance are shown.

Test	*A*	*X*	*D*	Z
Kunda	WHG	Baltic_LN	0.0149	4.338
		EHG	0.0173	3.887
		Narva	0.0159	3.651
		SHG	0.0145	3.547
		Steppe_EMBA_Poltavka	0.0139	3.545
		Steppe_EMBA_Yamnaya_Kalmykia	0.013	3.497
		Baltic_BA	0.0112	3.215
		Iran_ChL	0.0115	3.119
		Steppe_Eneolithic_Samara	0.0152	3.096
		Steppe_EMBA_Afanasievo	0.0117	3.002
Narva	Kunda	No significant results		
Narva	WHG	EHG	0.0163	5.412
		Steppe_EMBA_Poltavka	0.0115	4.265
		Baltic_BA	0.0099	4.18
		Steppe_EMBA_Afanasievo	0.0101	3.874
		CordedWare_Baltic	0.009	3.868
		Steppe_Eneolithic_Samara	0.0114	3.597
		CordedWare_Central	0.0085	3.588
		Iran_HotuIIIb	0.0178	3.582
		Yamnaya_Samara	0.009	3.571
		Steppe_MLBA_Poltavka_outlier	0.0122	3.411
		Steppe_MLBA_Srubnaya	0.0078	3.381
		SHG	0.0099	3.365
		Steppe_EMBA_Yamnaya_Kalmykia	0.0083	3.231
		Armenia_ChL	0.0079	3.172
		Europe_LNBA_Unetice	0.0071	3.15
Baltic_LN	CordedWare_Central	No significant results		
Baltic_LN	Yamnaya_Samara	Europe_EN_Iberia	0.0109	5.047
		Europe_MNChL_Hungary	0.013	4.808
		Europe_MNChL_Iberia_Chalcolithic	0.009	4.785
		Kunda	0.0137	4.769
		Europe_EN_Hungary	0.0089	4.694
		Switzerland_HG	0.0125	4.467
		Europe_MNChL_Iberia	0.0088	4.186
		Levant_N	0.0087	4.055
		Narva	0.0092	3.888
		Europe_EN_LBK	0.0068	3.632
		Europe_MNChL_Central	0.0083	3.623
		WHG	0.0087	3.499
		Europe_EN_Starcevo	0.0131	3.447
		EN_TRB	0.0097	3.392
		Europe_MNChL_Remedello	0.0088	3.301
		Anatolia_N	0.0058	3.175
Baltic_BA	Baltic_LN	Narva	0.025	11.679
		WHG	0.0249	11.18
		Europe_EN_Hungary	0.0174	9.431
		Europe_MNChL_Iberia_Chalcolithic	0.0153	8.359
		Anatolia_N	0.0148	8.172
		Europe_EN_LBK	0.0149	8.141
		Levant_BA	0.0151	7.841
		Europe_MNChL_Iberia	0.016	7.831
		Europe_LNBA_Hungary	0.0167	7.634
		Kunda	0.0211	7.44
		SHG	0.0159	7.364
		Switzerland_HG	0.0202	7.284
		Europe_MNChL_Central	0.014	6.428
		Europe_LNBA_BellBeaker	0.0104	6.199
		EN_TRB	0.0164	6.157
		Levant_N	0.0132	6.067
		Europe_LNBA_Vatya	0.0131	5.877
		Europe_LNBA_Central	0.0101	5.575
		Europe_EN_Iberia	0.0116	5.567
		Europe_MNChL_Hungary	0.0142	5.371
		PWC	0.0132	5.339
		Europe_LNBA_Unetice	0.0095	5.254
		MN_TRB	0.0121	4.899
		Anatolia_ChL	0.0125	4.749
		Armenia_ChL	0.0084	4.583
		Steppe_MLBA_Srubnaya	0.0077	4.533
		Armenia_EBA	0.0084	4.203
		Natufian	0.0112	4.101
		Europe_MNChL_Remedello	0.0102	4.063
		Iran_ChL	0.0064	3.444
		Europe_LNBA_Nordic_LBA	0.0152	3.437
		CordedWare_Central	0.0062	3.406
		Europe_EN_Starcevo	0.012	3.26
		Europe_EN_LBKT	0.0162	3.017

Supplementary Information Table S3. Significantly positive results for *D*(*Ancient Scandinavian population*, A;*X*, Mbuti). A is a geographically or chronologically proximate population and *X* is every other ancient population. This test shows if *Test* shares significantly more alleles with *X* than A does with *X* when Z>3.

Test	***A***	***X***	***D***	**Z**
SHG	WHG	EHG	0.0422	12.797
		Steppe_Eneolithic_Samara	0.0329	9.756
		MA1	0.0347	8.319
		Steppe_EMBA_Poltavka	0.0216	7.377
		Steppe_EMBA_Yamnaya_Samara	0.0201	7.347
		Steppe_EMBA_Yamnaya_Kalmykia	0.0198	7.133
		PWC	0.0235	6.328
		Steppe_EMBA_Srubnaya	0.0269	6.22
		Steppe_EMBA_Afanasievo	0.0176	5.953
		Clovis	0.0224	5.844
		Kennewick	0.0211	5.106
		CordedWare_Baltic	0.0118	4.326
		Europe_LNBA_CordedWare_Central	0.0107	4.164
		Steppe_EMBA_Russia_EBA	0.0204	4.081
		Steppe_IA	0.0148	4.029
		Iran_N	0.0135	4.002
		AG2	0.0239	3.85
		Armenia_ChL	0.0097	3.643
		Iran_LN	0.0133	3.54
		Iran_HotuIIIb	0.0179	3.327
		Steppe_MLBA_Srubnaya	0.0084	3.323
PWC	SHG	No significant results		
EN_TRB	Europe_MNChL_Central	No significant results		
MN_TRB	EN_TRB	No significant results		
MN_TRB	Europe_MNChL_Central	PWC	0.0221	4.627
Scandinavia LNBA	Baltic_LN	Europe_EN_LBK	0.0093	4.458
		Anatolia_N	0.0088	4.329
		Europe_EN_Iberia	0.0099	4.017
		Europe_EN_Hungary	0.0081	3.866
		Europe_MNChL_Iberia	0.0087	3.65
		Europe_MNChL_Remedello	0.0097	3.227
		Europe_MNChL_Iberia_Chalcolithic	0.0068	3.183
Scandinavia LNBA	Europe LNBA Corded Ware Central	No significant results		
Olsund	Baltic_LN	Levant_BA	0.0183	5.073
		Anatolia_N	0.0131	4.024
		Levant_N	0.0156	3.913
		Europe_EN_LBK	0.0128	3.81
		Armenia_EBA	0.0127	3.63
		Anatolia_ChL	0.0164	3.398
		Europe_MNChL_Iberia	0.0118	3.106
		Europe_MNChL_Iberia_Chalcolithic	0.0101	3.011
		Europe_EN_Hungary	0.0103	3.005
Olsund	Scandinavia LNBA	Levant_BA	0.0106	3.082

Supplementary Information Table S4. *qpWave* analysis of eastern Baltic populations showing possible waves of admixture. Tests that are not rejected (p>0.05) are marked in red.

Test	Reference A	Reference B	Rank 0 p-value	Rank 1 p-value	1 source	2 sources
Kunda	WHG		1.79E-01		not rejected	
Kunda	WHG	SHG	2.73E-95	7.58E-01	rejected	not rejected
Kunda	WHG	EHG	6.94E-204	8.18E-01	rejected	not rejected
Narva	Kunda		1.16E-01		not rejected	
Narva	WHG		8.55E-15		rejected	
Narva	WHG	SHG	1.19E-97	4.54E-01	rejected	not rejected
Narva	WHG	EHG	1.05E-03	43.4E-01	rejected	not rejected
Narva	Kunda	SHG	7.21E-46	4.55E-01	rejected	not rejected
Narva	Kunda	EHG	5.11E-174	3.61E-01	rejected	not rejected
Narva	Kunda	WHG	1.41E-09	5.54E-01	rejected	not rejected
NarvaEast (Kretuonas)	Kunda		8.17E-04		rejected	
NarvaEast (Kretuonas)	Kunda	EHG	2.69E-138	1.22E-01	rejected	not rejected
NarvaEast (Kretuonas)	Kunda	WHG	1.19E-14	4.33E-01	rejected	not rejected
NarvaEast (Kretuonas)	Kunda	SHG	7.01E-31	1.41E-01	rejected	not rejected
NarvaWest	Kunda		7.27E-01		not rejected	
NarvaWest	Kunda	WHG	2.68E-02	6.99E-01	rejected	not rejected
NarvaWest	Kunda	SHG	3.03E-45	7.65E-01	rejected	not rejected
NarvaWest	Kunda	EHG	9.09E-163	6.57E-01	rejected	not rejected
Baltic_LN	CordedWare_Central		1.17E-01		not rejected	
Baltic_LN	Steppe_EMBA		1.59E-13		rejected	
Baltic_LN_Sope	CordedWare_Central		9.74E-02		not rejected	
Baltic_LN_Sope	Steppe_EMBA		3.35E-07		rejected	
Baltic_LN_Sope	Narva		2.65E-72		rejected	
Baltic_LN_Plinkaigalis241	CordedWare_Central		4.63E-01		not rejected	
Baltic_LN_Plinkaigalis241	Steppe_EMBA		4.70E-03		rejected	
Baltic_LN_Plinkaigalis241	Narva		3.96E-61		rejected	
Baltic_LN_Plinkaigalis242	CordedWare_Central		6.62E-04		rejected	
Baltic_LN_Plinkaigalis242	Steppe_EMBA		1.87E-01		not rejected	
Baltic_LN_Plinkaigalis242	Narva		1.48E-131		rejected	
Baltic_LN_Spiginas2	CordedWare_Central		8.08E-07		rejected	
Baltic_LN_Spiginas2	Steppe_EMBA		4.68E-16		rejected	
Baltic_LN_Spiginas2	Narva		8.44E-68		rejected	
Baltic_LN_Spiginas2	CordedWare_Central	Narva	1.38E-242	1.80E-01	rejected	not rejected
Baltic_LN_Kunila	CordedWare_Central		9.67E-01		not rejected	
Baltic_LN_Kunila	Steppe_EMBA		8.73E-04		rejected	
Baltic_LN_Kunila	Narva		1.63E-78		rejected	
Baltic_LN_Gyvakarai	CordedWare_Central		4.88E-03		rejected	
Baltic_LN_Gyvakarai	Steppe_EMBA		4.06E-01		not rejected	
Baltic_LN_Gyvakarai	Narva		1.49E-146		rejected	
CordedWare_Central	Baltic_LN	MNChL_Central	3.18E-21	1.34E-01	rejected	not rejected
Baltic_BA	Baltic_LN		1.96E-11		rejected	
Baltic_BA	Baltic_LN	Narva	1.18E-255	1.14E-02	rejected	rejected
Baltic_BA	Baltic_LN	CordedWare_Central	1.63E-13	2.03E-02	rejected	rejected
Lithuanian	Baltic_BA		1.26E-03		rejected	
Estonian	Baltic_BA		3.97E-11		rejected	

Supplementary Information Table S5. ***qpWave*** **analysis of Scandinavian populations showing possible waves of admixture.** Tests that are not rejected (p>0.05) are marked in red.

Test	Reference A	Reference B	Rank 0 p-value	Rank 1 p-value	1 source	2 sources
SHG	WHG		1.33E-98		rejected	
SHG	EHG		2.83E-77		rejected	
SHG	Kunda		3.42E-25		rejected	
SHG	Kunda	EHG	9.36E-109	6.59E-01	rejected	not rejected
SHG	WHG	EHG	2.48E-219	5.53E-01	rejected	not rejected
PWC	SHG		6.31E-07		rejected	
PWC	Kunda		4.56E-24		rejected	
PWC	Narva		7.87E-36		rejected	
PWC	Kunda	EN_TRB	1.95E-37	1.10E-03	rejected	rejected
PWC	Kunda	MN_TRB	5.10E-58	4.20E-04	rejected	rejected
PWC	Kunda	MNCHL_Central	6.59E-78	3.40E-05	rejected	rejected
PWC	Narva	EN_TRB	6.22E-59	2.29E-03	rejected	rejected
PWC	Narva	MN_TRB	1.56E-86	1.25E-04	rejected	rejected
PWC	Narva	MNCHL_Central	1.31E-126	3.24E-04	rejected	rejected
PWC	SHG	EN_TRB	9.92E-31	8.68E-02	rejected	not rejected
PWC	SHG	MN_TRB	5.71E-43	4.41E-02	rejected	rejected
PWC	SHG	MNCHL_Central	1.38E-66	4.44E-02	rejected	rejected
EN TRB	MNCHL_Central		2.60E-01		not rejected	
EN TRB	Iberia_MN		5.00E-01		not rejected	
EN TRB	Iberia_ChL		5.40E-01		not rejected	
EN TRB	MNCHL_Central	Narva	3.67E-83	2.15E-01	rejected	not rejected
EN TRB	MNCHL_Central	Kunda	1.49E-50	2.56E-01	rejected	not rejected
EN TRB	MNCHL_Central	PWC	3.89E-12	1.93E-01	rejected	not rejected
EN TRB	MNCHL_Central	WHG	2.07E-123	2.14E-01	rejected	not rejected
EN TRB	MNCHL_Central	SHG	1.41E-55	2.51E-01	rejected	not rejected
MN TRB	MNCHL_Central		7.71E-01		not rejected	
MN TRB	EN TRB		8.58E-01		not rejected	
MN TRB	EN_TRB	Narva	8.52E-74	8.39E-01	rejected	not rejected
MN TRB	EN_TRB	PWC	4.77E-09	7.87E-01	rejected	not rejected
MN TRB	EN_TRB	SHG	8.20E-41	8.28E-01	rejected	not rejected
MN TRB	MNCHL_Central	Narva	1.03E-126	7.33E-01	rejected	not rejected
MN TRB	MNCHL_Central	PWC	8.51E-20	8.05E-01	rejected	not rejected
Scandinavia LNBA	CordedWare_Central		4.11E-04		rejected	
Scandinavia LNBA	Baltic_LN		4.54E-04		rejected	
Scandinavia LNBA	CordedWare_Central	MN_TRB	2.13E-10	3.54E-01	rejected	not rejected
Scandinavia LNBA	Baltic_LN	MN_TRB	9.50E-14	6.97E-01	rejected	not rejected
Scandinavia LNBA	CordedWare_Central	PWC	9.91E-36	2.61E-03	rejected	rejected
Scandinavia LNBA	Baltic_LN	PWC	3.91E-31	6.11E-03	rejected	rejected
Olsund	Scandinavia LNBA		2.68E-03		rejected	
Olsund	Baltic_LN		6.98E-03		rejected	
Olsund	Baltic_LN	Narva	3.07E-224	4.25E-03	rejected	rejected
Olsund	Baltic_LN	SHG	4.50E-87	9.01E-03	rejected	rejected
Olsund	Scandinavia LNBA	SHG	1.91E-74	4.61E-03	rejected	rejected
Olsund	Baltic_LN	PWC	3.83E-32	9.27E-03	rejected	rejected
Olsund	Scandinavia LNBA	PWC	1.40E-26	8.85E-03	rejected	rejected
Olsund	Baltic_LN	MN_TRB	4.39E-11	4.71E-02	rejected	rejected
Olsund	Scandinavia LNBA	MN_TRB	3.60E-06	2.40E-02	rejected	rejected

Supplementary Information Table S6. *qpAdm* analysis of admixture proportions in ancient eastern Baltic populations.

Test	**Source**		**Admixture coefficient**		**Std. error**		**p-value**
	A	**B**	**A**	**B**	**A**	**B**	
Kunda	WHG	SHG	84.54%	15.46%	5.20%	5.20%	7.58E-01
Kunda	WHG	EHG	91.78%	8.22%	2.60%	2.60%	8.18E-01
Narva	WHG	SHG	69.68%	30.32%	3.10%	3.10%	4.54E-01
Narva	WHG	EHG	85.51%	14.49%	1.50%	1.50%	4.34E-01
Narva	Kunda	SHG	82.77%	17.23%	5.60%	5.60%	4.55E-01
Narva	Kunda	EHG	92.71%	7.29%	2.60%	2.60%	3.61E-01
Narva	Kunda	WHG	infeasible				
NarvaEast (Kretuonas)	Kunda	EHG	86.61%	13.39%	3.00%	3.00%	1.22E-01
NarvaEast (Kretuonas)	Kunda	WHG	infeasible				
NarvaEast (Kretuonas)	Kunda	SHG	67.43%	32.57%	6.70%	6.70%	1.41E-01
NarvaWest	Kunda	WHG	infeasible				
NarvaWest	Kunda	SHG	93.50%	6.50%	6.10%	6.10%	7.65E-01
NarvaWest	Kunda	EHG	97.37%	2.63%	2.80%	2.80%	6.46E-01
Baltic_LN_Spiginas2	CordedWare_Central	Narva	77.85%	22.15%	3.60%	3.60%	1.53E-01

Supplementary Information Table S7. *qpAdm* analysis of admixture proportions in ancient Scandinavian populations.

Test	Source		Admixture coefficient		Std. error		p-value
	A	B	A	B	A	B	
SHG	Kunda	EHG	62.31%	37.63%	2.60%	2.60%	6.59E-01
SHG	WHG	EHG	57.53%	42.47%	1.80%	1.80%	5.53E-01
PWC	SHG	EN_TRB	91.11%	8.89%	3.30%	3.30%	8.68E-02
EN_TRB	MNChL_Central	Narva	95.93%	4.07%	9.90%	9.90%	2.15E-01
EN_TRB	MNChL_Central	Kunda	96.65%	3.35%	3.40%	3.40%	2.56E-01
EN_TRB	MNChL_Central	WHG	98.45%	1.55%	4.60%	4.60%	2.15E-01
EN_TRB	MNChL_Central	SHG	96.25%	3.75%	6.20%	6.20%	2.51E-01
MN_TRB	EN_TRB	Narva	96.57%	3.53%	5.10%	5.10%	8.39E-01
MN_TRB	EN_TRB	PWC	93.51%	6.49%	11.00%	11.00%	7.87E-01
MN_TRB	EN_TRB	SHG	97.32%	2.68%	7.50%	7.50%	8.28E-01
MN_TRB	MNChL_Central	Narva	97.71%	2.29%	3.30%	3.30%	7.33E-01
MN_TRB	MNChL_Central	PWC	96.34%	3.66%	7.00%	7.00%	8.05E-01
Scandinavia LNBA	CordedWare_Central	MN_TRB	70.99%	29.01%	7.20%	7.20%	4.36E-01
Scandinavia LNBA	Baltic_LN	MN_TRB	67.59%	32.41%	6.80%	6.80%	7.17E-01

Supplementary Information Table S8. Significantly positive results for *D*(*Modern eastern Baltic population*, Baltic_BA;*X*, Mbuti). We tested all modern populations for *X*. This test shows if *Test* shares significantly more alleles with *X* than A does with *X* when Z>3. The 40 most significant tests are shown for each.

Test	*A*	*X*	*D*	Z
Lithuanian	Baltic_BA	Kurd	0.0094	5.938
		Druze	0.0073	5.936
		BedouinA	0.007	5.821
		Karaim	0.0075	5.604
		Libyan	0.0075	5.587
		Sicilian	0.0071	5.586
		Sardinian	0.0073	5.578
		Lebanese	0.0071	5.537
		Palestinian	0.0067	5.526
		BedouinB	0.0075	5.514
		Egyptian	0.0065	5.501
		Assyrian_WGA	0.0075	5.446
		Jew_Yemenite	0.0074	5.401
		Jew_Moroccan	0.0072	5.394
		Lebanese_Muslim	0.0069	5.388
		Cypriot	0.0074	5.387
		Jordanian	0.0071	5.355
		Jew_Libyan	0.007	5.306
		Jew_Ethiopian	0.0061	5.234
		Jew_Tunisian	0.0071	5.222
		Moroccan	0.006	5.157
		Saudi	0.007	5.145
		Lebanese_Christian	0.0069	5.126
		Armenian	0.0068	5.096
		Jew_Iranian	0.007	5.05
		Turkish	0.0062	5.049
		Jew_Turkish	0.0069	5.045
		Ain_Touta	0.0072	5.038
		Assyrian	0.0067	5.031
		Ezid	0.0066	4.99
		Georgian	0.0065	4.94
		Armenian	0.0073	4.876
		Maltese	0.0065	4.874
		Jew_Georgian	0.0066	4.87
		Tunisian	0.0059	4.838
		Yemeni	0.0063	4.807
		Jew_Iraqi	0.0066	4.741
		Spanish	0.0058	4.711
		Turkish_Balikesir	0.0066	4.654
		Greek	0.006	4.619
Estonian	Baltic_BA	Tu	0.0082	5.146
		Naxi	0.0078	4.84
		Yi	0.0078	
		Mongola	0.0077	4.722
		Kinh	0.0073	4.619
		Han	0.007	4.473
		Borneo	0.007	4.426
		Nanai	0.0072	4.315
		Dungan	0.0066	4.294
		Negidal	0.0078	4.283
		Evenk_Transbaikal	0.0071	4.281
		Japanese	0.0068	4.255
		Ulchi	0.0068	4.242
		Assyrian	0.006	4.22
		Hezhen	0.0069	4.201
		Kalmyk	0.0064	4.199
		Nganasan	0.0069	4.191
		Cambodian	0.0066	4.179
		Xibo	0.0066	4.17
		Semende	0.0068	4.154
		Dai	0.0066	4.126
		Tujia	0.0066	4.124
		Lahu	0.0066	4.098
		Nivh	0.0068	4.061
		Korean	0.0068	4.059
		Miao	0.0067	4.043
		Mongol	0.0059	4.03
		Khakass_Kachins	0.0062	3.995
		Druze	0.0051	3.987
		She	0.0065	3.963
		Itelmen	0.007	3.962
		Thai	0.0062	3.948
		Oroqen	0.0065	3.927
		Kurd_WGA	0.0064	3.926
		Jew_Ethiopian	0.0048	3.921
		Ami	0.0066	3.888
		BedouinA	0.0048	3.883
		Buryat	0.0059	3.822
		Palestinian	0.0047	3.814

Supplementary Information Table S9. Significantly positive results for *D*(EHG/SHG, *Hunter-Gatherer*; MA1/AG3, Mbuti). This test shows if EHG or SHG shares significantly more alleles with MA1 or AG3 (signifiying ANE ancestry) than another ancient *HG* group does with MA1 or AG3 when Z>3.

Test	*HG*	MA1/AG3	*D*	Z
EHG	CHG	AfontovaGora3	0.1388	23.541
	WHG	AfontovaGora3	0.1154	22.441
	Narva	AfontovaGora3	0.0987	19.766
	CHG	MA1	0.0975	17.873
	PWC	AfontovaGora3	0.093	15.232
	Kunda	AfontovaGora3	0.0971	13.911
	WHG	MA1	0.0654	13.752
	SHG	AfontovaGora3	0.0698	13.375
	Narva	MA1	0.0587	12.515
	PWC	MA1	0.0573	10.587
	Kunda	MA1	0.0601	10.117
	SHG	MA1	0.0343	7.612
SHG	CHG	AfontovaGora3	0.0754	13.964
	CHG	MA1	0.065	12.64
	WHG	AfontovaGora3	0.0507	10.834
	WHG	MA1	0.0347	8.319
	Narva	AfontovaGora3	0.0307	7.388
	Narva	MA1	0.0265	7.186
	PWC	MA1	0.0257	5.173
	Kunda	MA1	0.0269	5.062
	Kunda	AfontovaGora3	0.0291	4.536
	PWC	AfontovaGora3	0.0269	4.535
	EHG	MA1	-0.0343	-7.612
	EHG	AfontovaGora3	-0.0698	-13.375

Supplementary Information Table S10. Significantly positive results for *D*(*Ancient Eastern Baltic population*, *A*; *X*, Mbuti) using only transversion sites. *A* is a geographically or chronologically proximate population and *X* is every other ancient population. This test shows if *a modern Baltic population* shares significantly more alleles with *X* than Baltic_BA does with *X* when Z>3. The thirty tests with highest significance are shown.

Test	A	X	D	Z
Kunda	WHG	SHG	0.0249	3.92
		CordedWare_Baltic	0.021	3.689
		BA_Baltic	0.0198	3.618
		Narva	0.0226	3.503
		Iran_ChL	0.0203	3.267
		Europe_LNBA_Unetice	0.0176	3.231
		Steppe_MLBA_Poltavka_outlier	0.0314	3.21
		Europe_LNBA_CordedWare_Germany	0.0172	3.206
		Steppe_EMBA_Poltavka	0.0203	3.198
		Steppe_IA	0.0259	3.134
		Europe_LNBA_Central	0.0191	3.113
		SHG	0.0249	3.92
Narva	Kunda	No significant results		
Narva	WHG	EHG	0.017	3.84
		Steppe_EMBA_Poltavka	0.0142	3.679
		BA_Baltic	0.012	3.448
		Steppe_EMBA_Yamnaya_Kalmykia	0.0126	3.391
		Malta_AfontovaGora3	0.0266	3.216
		SHG	0.0132	3.214
		Steppe_EMBA_Afanasievo	0.0125	3.186
		Europe_LNBA_Unetice	0.0112	3.124
Baltic_LN	CordedWare_Central	No significant results		
Baltic_LN	Yamnaya_Samara	Europe_MNChL_Iberia_Chalcolithic	0.014	4.78
		Europe_MNChL_Iberia	0.0147	4.547
		Kunda	0.0206	4.488
		Europe_EN_Iberia	0.0149	4.335
		Villabruna_Villabruna	0.0176	4.175
		Europe_EN_LBK	0.0102	3.723
		Narva	0.0126	3.66
		Europe_MNChL_Central	0.0134	3.634
		Switzerland_HG	0.0136	3.286
		Europe_EN_Hungary	0.0097	3.278
		Europe_MNChL_Remedello	0.0149	3.274
		WHG	0.011	3.188
		Anatolia_N	0.0083	3.079
Baltic_BA	Baltic_LN	Villabruna_Villabruna	0.032	7.603
		Narva	0.0233	7.194
		WHG	0.0225	7.015
		Europe_EN_Hungary	0.016	5.52
		Villabruna_Ranchot88	0.0278	5.439
		Anatolia_N	0.0139	5.103
		Kunda	0.022	4.865
		Switzerland_HG	0.0194	4.826
		Europe_EN_LBK	0.0131	4.794
		SHG	0.0157	4.694
		Europe_MNChL_Hungary	0.0188	4.658
		Europe_MNChL_Iberia	0.014	4.409
		Europe_MNChL_Iberia_Chalcolithic	0.0127	4.353
		EN_TRB	0.0224	4.326
		Levant_BA	0.0133	3.964
		Villabruna_Chaudardes1	0.0432	3.874
		Europe_LNBA_Hungary	0.0131	3.701
		ElMiron_ElMiron	0.0158	3.546
		Levant_N	0.0128	3.451
		Europe_LNBA_Vatya	0.0126	3.363
		PWC	0.0124	3.335
		Armenia_ChL	0.0098	3.255
		Anatolia_ChL	0.0146	3.169
		Dolni_Vestonice16	0.0128	3.007

Supplementary Information Table S11. Significantly positive results for *D*(*Ancient Scandinavian population*, A;*X*, Mbuti) using only transversion sites. A is a geographically or chronologically proximate population and *X* is every other ancient population. This test shows if *Test* shares significantly more alleles with *X* than A does with *X* when Z>3.

Test	*A*	*X*	*D*	*Z*
SHG	WHG	EHG	0.0405	8.707
		Malta_AfontovaGora3	0.0594	7.28
		MA1	0.0334	5.808
		Steppe_Eneolithic_Samara	0.0313	5.787
		PWC	0.0255	4.994
		Steppe_EMBA_Yamnaya_Kalmykia	0.0181	4.508
		Steppe_EMBA_Poltavka	0.0181	4.402
		Steppe_EMBA_Yamnaya_Samara	0.0165	4.326
		Steppe_EMBA_Afanasievo	0.014	3.285
PWC	SHG	No significant results		
EN_TRB	Europe_MNChL_Central	No significant results		
MN_TRB	EN_TRB	Steppe_MLBA_Andronovo	0.0353	3.753
		Iberia_BA	0.055	3.055
MN_TRB	Europe_MNChL_Central	PWC	0.0356	4.52
		WHG	0.025	4.018
		EHG	0.0231	3.247
Scandinavia LNBA	Baltic_LN	Anatolia_N	0.0113	3.678
		Europe_EN_Iberia	0.0142	3.539
		Europe_EN_LBK	0.0111	3.531
		Europe_EN_Hungary	0.0107	3.181
		Europe_MNChL_Iberia	0.0122	3.152
Scandinavia LNBA	Europe LNBA Corded Ware Central	Europe_EN_Iberia	0.0127	3.256
Olsund	Baltic_LN	Europe_MNChL_Iberia	0.0204	3.374
		Armenia_EBA	0.0192	3.336
		Levant_BA	0.0195	3.285
Olsund	Scandinavia LNBA	No significant results		

Supplementary Information 1
Archeological context and sample description

This section provides archeological context for the 24 individuals for whom we report new genome-wide data, as well as the additional 81 human remains that were screened for this study. We also give a general overview of the prehistory of the Eastern Baltic and Scandinavian region as understood through archeology. Uncalibrated radiocarbon dates are in BP, calibrated radiocarbon dates are given at 94.5% confidence interval (calBCE), contextual archeological dating is given in BCE.The radiocarbon dates are not corrected for potential reservoir effects.

A tabular overview of information from all samples and their sequencing results is given in Supplementary Data Table 1.

The Eastern Baltic Region

Despite the similarities in the material culture and the smallness of the region, chronologies of the prehistory in the Baltic States varies, and to understand the context properly these have to be introduced first (Supplementary Information Section 1 Table S1).

Supplementary Information Section 1 Table S1. Chronology of prehistoric cultures in the eastern Baltic region.

<table>
<tr><th></th><th colspan="2">Estonia
(after Kriiska 2009; Lang 2007a, b)</th><th colspan="2">Latvia
(after Loze 2000; Zagorska 2001; Lang 2007b)</th><th colspan="2">Lithuania
(after Antanaitis-Jacobs & Girinikas 2002; Antanaitis-Jacobs et al. 2012; Lang 2007b)</th></tr>
<tr><td rowspan="3">Mesolithic (9000–4300/ 4100)</td><td>Early Mesolithic (9000–7000)</td><td rowspan="2">Kunda Culture (9000–4900)</td><td>Early Mesolithic</td><td>Pulli Culture (9000–6500)</td><td rowspan="2">Early Mesolithic (9000–6000)</td><td rowspan="2">Kunda Culture (9000–5300)</td></tr>
<tr><td rowspan="2">Late Mesolithic (7000–4200)</td><td>Middle Mesolithic</td><td>Kunda Culture (6500–5400)</td></tr>
<tr><td>Narva Culture (4900–4200)</td><td>Late Mesolithic</td><td rowspan="2">Narva Culture (5400–4100)</td><td>Late Mesolithic (6000–4550/4300)</td><td rowspan="4">Narva Culture (5300–1750)

Nemunas Culture (5100 – 3500)</td></tr>
<tr><td rowspan="3">Neolithic (4200–1800)</td><td>Early Neolithic (4200–3600)</td><td>Typical Combed Ware Culture (4200–3600)</td><td>Early Neolithic</td><td>Early Neolithic (4550/4300–3600/3400)</td></tr>
<tr><td rowspan="2">Late Neolithic (3600–1800)</td><td rowspan="2">Late Combed Ware (3600–1800) / Corded Ware (2900–1800)</td><td>Middle Neolithic (4100–2900)</td><td>Combed Ware and East Baltic Ware Cultures</td><td>Middle Neolithic (3600/3400–2400/2300)</td></tr>
<tr><td>Late Neolithic (2900–1800/1500)</td><td>Corded Ware and Abora I Ware Cultures</td><td>Late Neolithic (2400/2300–1800/1500)</td></tr>
<tr><td rowspan="3">Bronze Age (1800–500)</td><td colspan="2">Early Bronze Age (1800 – 1300)</td><td colspan="2">Early Bronze Age (1800/1500–1100)</td><td colspan="2">Early Bronze Age (1800/1500–1300/1100)</td></tr>
<tr><td colspan="2">Middle Bronze Age (1300–900)</td><td colspan="2" rowspan="2">Late Bronze Age (1100–500)</td><td colspan="2" rowspan="2">Late Bronze Age (1300/1100–500)</td></tr>
<tr><td colspan="2">Late Bronze Age (900–500)</td></tr>
</table>

All dates given in BCE.

Despite the differences in the dates these chronologies highlight the following archaeologically visible turning points in the prehistory of the Eastern Baltic: (1) initial colonization of the region; (2) transition of subsistence relying on terrestrial mammals to the sea resources; (3) beginning of pottery production by hunter-gatherers; (4) influx of exotic resources; (5) introduction of farming and crop cultivation; and (6) introduction of first metal objects and metallurgy.

Initial colonization of the Eastern Baltic region occurred after the retreat of the ice sheets in the first half of the 9th millennium BCE and following centuries. The pioneering settlers arrived from south and thus the first settlements are known from the territory of Southern-Lithuania and Latvia (already 11 000 BCE; Zagorska 1999; Kriiksa & Tvauri 2002), whereas the northern shores of Estonia were inhabited a bit later. During ca. 9000–8500 BCE natural sources of flint, manufacturing techniques and analogous forms of bone and antler artefacts as well as similarities of lithic technologies point to the existence of extensive networks in the European Boreal zone (Kriiska 2015). From ca. 8000 BCE a transition from Paleolithic cultures to the Mesolithic Kunda Culture is seen. The name-giving site Kunda Lammasmägi was discovered already in 1870s during the marl mining (Grewingk 1881; Indreko 1948). The abundant bone material together with small items from mainly quartz hint on a variety of activities on the site (Indreko 1948; Jaanits et al. 1982). The dominant species was elk (Lõugas 1996), while fish and seal bones appeared to be rare, indicating a subsistence dominated by terrestrial mammals (Indreko 1948; Lõugas 1996). In general, Kunda Culture, is characterized by inland camp sites on the shores of larger rivers and lakes, the main pray came from forests – being elk and beaver (Kriiska & Tvauri 2002) and the flint technology aiming at using the all the available source material to produce flakes to make small items was prevalent (see e.g. Kriiska et al. 2011). At the second half of the Kunda period, during the 7th millennium BCE the habitation spread to coast and further to the islands of the Baltic Sea (Kriiska 2009). During the Littorina Sea phase in the Baltic Sea basin hunting of marine mammals became important. From the beginning of the period there are no burial sites known; the earliest human remains – from the end of Kunda period – are known from the Zvejnieki cemetery in Northern Latvia (Zagorsksa 2006; Mannermaa et al. 2007).

The beginning of pottery production at the region dates back to the 6th millennium BCE being a cultural loan and an invention of hunter-gatherers. This period is named after the sites discovered in Narva area at the North-Eastern Estonia. As the successor of the Kunda Culture, the Narva Culture emerged around ca. 5500 BCE in the eastern inland Baltic region and spread north-, south and coastward in the following millennium, occupying the same region as the Kunda Culture (Jaanits 1965b). In Estonia Narva Culture is distinguished only in the Late Mesolithic phase, whereas both in Latvia and Lithuania it continues to the Neolithic (Supplementary Information Section 1 Table S1). Despite this technological innovation of pottery production there were no marked changes in the life ways or usages of raw materials of hunter-gatherers in the Eastern Baltic region. Continuity with the Mesoltihic tradition is seen in production and use of bone and antler artefacts. Also continued is the subsistence strategy of foraging, and numerous finds show evidence fore reliance on fishing (Loze 1993, Rimantienė 1994). In Estonia the majority of the sites are located on the coast (Kriiska & Tvauri 2002) and seal-hunting grew in importance, with presumably specialized seasonal sites for this puropose found on Estonian islands (Kriiska & Lõugas 1999). In the Middle Neolithic first sparse evidence is found in Narva sites for domesticated plants and animals but foraging ramins the dominant economy (Rimantienė 1994). Assemblages of the Narva Culture persist in its southern occupational area until the Late Neolithic (Antanaitis-Jacobs & Girininkas 2002).

The chronologically and geographically overlapping Combed Ware Culture of pottery producing hunter-gatherers to the north exhibited geographically extensive and intensive spread of foreign materials and artefacts, especially during Early Neolithic. On the territory of present-day Estonia flint, amber and metatuff from foreign sources were widely used. For example, flint is most likely from the upper reaches of the Volga River, but also from South Lithuania or Belarus. The origin of amber is difficult to detect, because the material and form are similar over an extensive area, most likely the amber came from Western Latvia and Western Lithuania. Metatuff used during the Stone Age on the territory of present day Estonia most likely came from the Onega region in Karelia in present day Russia; most numerous artefact made of metatuff is Russian-Karelian type of wood chopping tool (Kriiska 2015 and references therein).

The process of Neolithization is different in the Eastern Baltic region from what is known in Central and Southern Europe, where the 'Neolithic package' is mostly defined by simultaneous emergence of pottery production, crop cultivation and herding of domesticated animals, sedentary life way, and monumental architecture. In the Eastern Baltic, it has been a long tradition that the pottery production solely defines the beginning of Neolithic, whereas the life ways of the people do not change that markedly. Recently, however, Kerkko Nordqvist and Aivar Kriiska have listed the characteristics of Neolithization in the region as the following (Nordqvist & Kriiska 2015, and references therein):

- Pottery – great local variability of ceramics, which exhibit further a mixture of local traditions, domestic innovations, and external influences. Many new lines of development, like cultivation and rock art, appear roughly simultaneously with the adoption of pottery, even if these phenomena become more pronounced or visible only much later, especially around and after 4000 calBCE.

- From the 5th millennium calBCE onwards the material culture and the variety of raw materials become increasingly versatile. The broadening selection of mineral raw materials is especially striking. The working of stone materials and, consequently, the properties of artefacts start to change as well.

- The large-scale appearance of imported raw materials and artefacts is another novelty: carboniferous and cretaceous flint, particular slates and metatuffites as well as amber – and objects made of them. These materials and artefacts were transported in fairly large quantities and over distances of several hundreds, in some cases well over a thousand kilometres. Some artefact groups like wood-chopping tools of Russian-Karelian type or Baltic amber ornaments even indicate some sort of mass- or specialised production from the 4th millennium calBCE onwards. The new exotic raw materials include also metal. The use of native copper started soon after 4000 calBCE in the Lake Onega region, from where it was also exported to Finland.

• Further, the formation or re-aligning of these contact or social networks and the changes they reflect or cause in the society are essential to the whole development discussed here. As mentioned above, the old 'borders', which derive from the Mesolithic remained visible after the adoption of pottery in the research area. However, the strong Neolithic impulse around 4000 calBCE, which can, for example, be mirrored against the distribution of Typical Comb Ware, transcends these borders and shows a significant change in the prevailing networks. After several centuries this situation was changing again (Nordqvist & Kriiska 2015, 543).

Recent aDNA studies have resolved the long-lasting debate between the migrationists and diffusionists about the origins of Corded Ware/Battle Axe Culture in the Eastern Baltic (see e.g. Lõugas et al. 2007). It has been shown that these populations migrated to the region from the area of Yamnaya culture at the Russian steppe (Haak et al. 2015, Allentoft et al. 2015). This took place during the first centuries of the 3rd millennium BCE. This migration also brought about the onset of food production as aregular form of substinence in all the present Baltic States (see e.g. Antanaitis-Jacobs & Girininkas 2002, 19; Tõrv 2016). However, the new way of life – agriculture – did not mean an end to the hunter-gatherer populations. These existed parallel in the Eastern Baltic region for a while (see e.g. Lõugas et al. 2007; Tõrv 2016). Differently from the hunter-gatherer sites the occupation layers of Corded Ware sites were rather thin (Kriiska & Tvauri 2002; Lõugas et al. 2007). Moreover, Corded Ware people preferred to settle farther from the shores of water-bodies, neither were their habitation sites known from the coastal areas (Lõugas et al. 2007). The culture is mostly defined by the abundant grave finds – inhumations in flexed limbs and a specific set of grave goods comprising of battle axes and pottery –, and stray finds of boat shaped axes.

The beginning of Bronze Age in the Eastern Baltic is defined by the occurrence of the first bronze items, changes in the material culture in general, and the spread of bronze work. The earliest indications on the local bronze work in the region derive from Latvia and Lithuania around 2000 BCE (Lang 2007b). The earliest bronze items show that Eastern Baltic tribes had contacts with different populations reaching from Scandinavia (Lang & Kriiska 2007) to Russia (Lang 2007a). Early Bronze Age has been seen as a transition period from Late Neolithic to the Late Bronze Age (Lang 2007a). Despite the fact that many areas inhabited tensely during the Late Neolithic were abandoned and areas more appropriate for land cultivation were adopted during the Early Bronze Age, many previously known sites still remained settled; also stone tools still played a major role in the everyday life. Differently from Estonia EBA cemeteries are known both from Latvia (earth graves and barrows) and Lithuania (barrows) (Lang 2007b).

The classical characteristics of Eastern Baltic Bronze Age become visible during the LBA. Some of the most significant antiquities from the LBA are the fortified settlements that are known from all three Baltic States (e.g. Iru, Asva, Kivutkalns, Vinakalns, Narkunai, Nevieriškes; Lang 2007b). Several families resided in these sites, it has been estimated that the typical community ranged between 30 to 50 members (Lang 2007a, 223). In addition to the EBA barrows known from Latvia and Lithuania there are also stone graves with above-ground constructions known from Estonia. These circular stone-cist graves are the most studied objects from the given period (Lang 2007a). Also boat graves and earth graves are known from this period. For the first time in the Eastern Baltic prehistory we have marks on ancient field-systems (clearance cairn filed, block-shaped fields: Baltic and Celtic fields) that are well studied in Estonia (Lang 2007a, b). These remarkable changes in material culture signify changes in the social structure and culture of the society. By the end of the period Eastern Baltic populations relied on economy fully focused on agriculture. These farming societies were characterized by stratified social structure developed ownership rights, rich material culture, and specific religious beliefs (Lang 2007a).

Kõnnu, Estonia

Kõnnu is located on the present island of Saaremaa at the Kõnnu village (Pihtla parish). During its habitation it was a separate island in Litorina Sea a couple of kilometres south-east from the larger island of Saaremaa (Jaanits 1979, 366; Kriiska 2007; Poska & Saarse 2002; Saarse et al. 2009a, b); according to analyses of the faunal material it has been argued to be a camp for seal hunting (Lõugas 1996, 105). The settlement and burial site was discovered during gravel mining in the spring of 1977. The archaeological investigations lead by Lembit Jaanits took place in 1977 and 1978 (as the gravel mining continued documentation of the finds were carried out in 1979–1986). Most of the find material consisted of small quartz artefacts; amongst flint artefacts only scrapers were distinguished, also remarkable number of tooth pendants and various types of ceramics were found (Jaanits 1979, 363–367).

The site is from Late Mesolithic and Early Neolithic, and is attributed to Kunda, Narva and Combed Ware Culture (Jaanits 1979, 367; Tõrv 2016, 128). The skeletal remains of four individuals were found in graves I, II, and III, whereas grave II contained the remains of two individuals (Jaanits 1979, 365–367; AI 4951). In addition to these single human bones were gathered from non-grave archaeological contexts (Tõrv 2016, 100).

The biological sex and age at death estimations, and radiocarbon dates taken from Tõrv (2016).

- Kõnnu I, juvenile, (KIA-49481, 6297±29 BP, 5320–5210 calBCE)

- Kõnnu IIa (prev. II), older child, (UBA-25997, 6222±33BP, 5310–5060 calBCE).
- Kõnnu IIb (prev. IIa), younger child. No direct radiocarbon dating.

Veibri quadruple burial, Estonia

The burial site is situated in south-eastern Estonia on a flood plain on the northern shore of the Suur Emajõgi River in the village of Veibri. The site was first discovered in 1997 and identified as a Corded Ware Culture and Medieval settlement site (Kriiska 1997); in 2003 bones exposed above the ground were detected. During the excavations (lead by Kristiina Johanson, Mari Lõhmus(Tõrv) and Tõnno Jonuks) of human skeletal remains a quadruple grave was unearthed. The archaeothanatological analyses revealed that this is a multiple burial (Tõrv 2016), thus the deceased were buried simultaneously (Allmäe 2011, Tõrv 2016); no grave goods were found despite Narva-type pottery sherd close to skeleton III (Kriiska et al. 2007).

The quadruple grave (TÜ 1424) is dated to the Late Mesolithic/Early Neolithic (Kriiska et al. 2007, Tõrv 2016), biological sex and age at death estimation from Allmäe (2011):

- Veibri I/I child 12, (Ua-43124, 5580±39, 4490–4340 calBCE); (UBA-2735, 55791±43, 4770–4530 calBCE).
- Veibri I/II female 25–32 yrs, (Hela-1331, 6090±45, 5210–4850 calBCE).
- Veibri I/III child 5 yrs, (KIA-48842, 5841±29, 4790–4610 calBCE).
- Veibri I/IV child 4 yrs , (KIA-48843, 5940±22, 4900–4720 calBCE).

Kivisaare, Estonia

Kivisaare settlement and burial site is located in the southern part of Estonia in Lalsi village, approximately 1.5 km from Põltsamaa River and 6 km from present shore of Lake Võrtsjärv (Kriiska et al. 2007). Here, the human skeletal remains have been found occasionally since 1882 during gravel mining. The around 30 individuals found there makes it one of the largest burial grounds in the present-day Estonia (Tõrv 2016). Several archaeological excavations on site have been conducted by different archaeologists since 1910 confirming human activity from Mesolithic to Bronze Age (Ottow 1911; Bolz 1914; Tallgren 1922; Indreko 1935; Jaanits et al. 1982, 100; Kriiska et al. 2003, 2004, 2007; Kriiska & Lõhmus 2005; Tõrv & Meadows 2015).

Kivisaare burials III, IIIa and IV were unearthed in 1960s (Jaanits 1965; AI 4379), IIIa burial was distinguished as a separate individual and labelled by Tõrv during osteological analysis (2016, 148). The burials under study are attributed to Narva Culture and Combed Ware Culture (Kriiska *et al.* 2007); Narva type pottery was found near Kivisaare IV burial (Kriiska et al. 2003). Radiocarbon dates of burials from Kriiska *et al.* (2007) and Tõrv (2016), biological sex and age at death estimations from Tõrv (2016).

- Kivisaare III, male? adult (UBA-25993, 5796±37BP, 4730–4540 calBCE)

- Kivisaare IIIa, adult. No direct radiocarbon dating.
- Kivisaare IV, older child (Poz-10840, 5450±40BP, 4370–4230 calBC; KIA-50905, 5705±35BP, 4680–4450 calBCE)

Naakamäe, Estonia

Naakamäe is a settlement and burial site in south-western part of Saaremaa island, and is attributed to the Typical and Late Combed Ware Culture (Jaanits 1965b; Jaanits et al. 1982, 77, 83, 85). The settlement site was excavated by Lembit Jaanits during 1958–1962; one burial was found at the edge of settlement area. The body was buried on its back with upper limbs slightly abducted at the shoulder, the latter being projected upwards, arms medially rotated, and forearms flexed at the elbow and pronated, the hands being slightly flexed on the wrist and rested in front of the abdomen; the lower extremities were both extended from the hip and knee (Tõrv 2016, 218). Beneath the skull ochre was found, and a bone awl (AI 4022) was placed next to left body side (Jaanits et al. 1982, 83).

The biological sex and age at death estimation from Karin Mark personal archive (TLU AI, F18), and radiocarbon date from Lõugas et al. 1996.

- Naakamäe I, female adult (Ua-4822; 4125±85, 2890–2480 calBCE)

Kõljala, Estonia

Kõljala is a burial site in southern part of Saaremaa island. Three burials were unearthed at Kõljala by Richard Hausmann in 1901 (Hausmann 1904; AI K35). Tooth pendants and slate ring ornaments made of metatuff were found with one skeleton. Based on the latter find the graves were dated to the second half of the 3rd millennium (Jaanits et al. 1982, 99–100), and attributed to the Combed Ware Culture (Tõrv 2016, 127).

The biological sex and age at death estimations, and radiocarbon dates after Tõrv (2016):

- Kõljala I, male? adult, (UBA-27363; 5180±44 BP, 4230–3810 calBCE)
- Kõljala III, male? adult, (UBA-25996; 4914±32 BP, 3770–3640 calBCE)

Tamula, Estonia

Tamula I settlement and burial site is located in southeastern Estonia on the north-eastern shore of Lake Tamula on a shallow cape Roosisaare, where Võhandu River joins the lake. The water level in Lake Tamula was lower during Stone Age than today therefore the cultural layer has been grown on the peat and sandmixed peat. Later the water level arose and the site was covered by lake sediments (Jaanits et al. 1982, 78).

Tamula I settlement and burial site was discovered in 1938, and has been archaeologically investigated during several decades: by Richard Indreko (1942–1943, AI 3932, burials I–III), by Harri Moora (1946, AI 3960, burials IV–VII) and by

Lembit Jaanits (1955–1956, 1961, 1968, 1988–1989; AI 4118, burials VIII–XXV). The settlement and burial site is attributed to Combed Ware and Corded Ware Culture (Jaanits et al. 1982, 78–83). Tamula is outstanding of its amber artefacts, 191 finds have been recorded there (Ots 2006, 42), and of bone artefacts, including tooth pendants (Jaanits *et al.* 1982, 78–82).

The skeletal remains of eight individuals were included to the study. The biological sex and age death estimations are given after Allmäe (2006); burial descriptions after lohmus (2005), Ots (2006), and Tõrv (2016) the radiocarbon dates from Lõugas *et al.* (1996), Kriiska et al. (2007), Mannermaa (2008), and Tõrv (2016).

- Tamula I, female 25–35 yrs, (Poz-15645 4680±40BP, 3630–3360 calBCE), buried on back, arms flexed from the elbow, with lower limbs flexed from the hip and the knee; grave goods present.
- Tamula III, male 25–35 yrs, (Poz-10826 4940±40BP, 3800–3640 calBCE), buried on back, arms and forearms flexed in front of the body and lower limbs flexed from the hip and knee, grave goods present.
- Tamula VI
- Tamula VII, child 8 yrs, (Hela-1335 5760±45BP, 4720–4500 calBCE), buried on back with both upper and lower extremities in extension; large bird bones and a stone; abundant grave goods present.
- Tamula VIII, female 18–25 yrs, (Hela-1336 5370±45BP, 4335–4055BC), buried on back with both upper and lower limbs in extension; wooden pole and branches; abundant grave goods present.
- Tamula IX male? 25-35 yrs.
- Tamula X, female 18–21 yrs, (Ua-4828 5310±85, 4330–3970 calBCE; UBA-27362 4902±52BP, 3890–3530 calBCE), buried on back, with both upper and lower limbs in extension; wooden branches; grave goods present.
- Tamula XI male? 18-25 yrs.
- Tamula XII child 2 yrs +-8 m.
- Tamula XIII child 2-3 yrs.
- Tamula XV, child ~1,5 yrs, buried on back, due to poor preservation the initial body position cannot be reconstructed entirely; grave goods present. No direct radiocarbon date.
- Tamula XVII, female 35–45 yrs, buried on back, with both upper and lower limbs in extension; grave goods present. No direct radiocarbon date.
- Tamula XVIII, female 25–35 yrs, buried on back, with upper limbs extended, lower limbs slightly flexed at knee; no grave goods (UBA-27359; 4696±39BP, 3640–3360 calBCE)

- Tamula XIX male 20–30 yrs.
- Tamula XX, male 25–35 yrs, buried on back, with both upper and lower limbs in extension; wooden branches; no grave goods. No direct radiocarbon date.
- Tamula XXI male 25–35 yrs.
- Tamula XXII, male? 25–35 yrs, (Ua-43123 4830±39BP 3700–3520 calBCE), buried on back with lower limbs hyper-flexed from the knee, placed behind the thighs; grave padded and covered with bark; no grave goods.
- Tamula XXIII male? adult.
- Tamula XXIV child, 2 yrs +-8 m.
- Tamula XXV adolescent.

<u>Ardu, Estonia</u>

Ardu cemetery is situated in Northern Estonia in the village of Ardu, in the area of the upper reaches of the Pirita River, 100 meters from the river, on a gravel hill rising above the surrounding river plain (Kriiska *et al.* 2007, Jaanits *et al.* 1982, 104). The site was discovered during gravel mining. Two burials – Ardu I burial (AI 2745) in 1931 and Ardu II burial (AI 3499) in 1936 – were uncovered, both individuals buried in flexed position lying on left lateral side: (Indreko 1931, Saadre 1936). According to grave goods, for example Karlova-type battle-axe, bone adzes, flint adze, flint knives, bone awls, bone buttons, Corded Ware shreds etc., the burials are attributed to the Corded Ware Culture (Jaanits *et al.* 1982, 104–109, 116).

The biological sex and age at death estimations from Karin Mark personal archive (TLU AI, F18); radiocarbon date of Ardu II skeleton (Poz-10824, 4110±40BP 2860–2580 calBCE 2880–2500 calBCE) from Kriiska *et al.* (2007) and Lõugas *et al.* (2007).

- Ardu I, male adult. No direct radiocarbon dating.

<u>Sope, Estonia</u>

Sope burial site is situated at Soonurme village in North-Eastern Estonia, 4 km east of Purtse and 2 km south of Jabara village, on the lands of Metsavälja farmstead, on a small sandy knoll on the bank of the Sope Stream (Jaanits *et al.* 1982, 102).

Human skeletal remains and boat-shaped axes have been found since 1880s at Sope. The first proper archaeological excavations at Sope were conducted by Harri Moora (1926), who uncovered strongly flexed female skeleton (Sope I; AI 2607). In 1933 Richard Indreko uncovered second female skeleton (Sope II; AI 3175) with legs flexed at knees, lying on her right body side, right hand beneath her head and left hand lying in front of the the body (Indreko 1933). Both graves contained grave goods: shell of freshwater pearl mussels, bone awls, ceramic vessel, and are attributed to the Corded Ware Culture (Jaanits *et al.* 1982, 102–109, 116; Kriiska *et al.* 2007).

The biological sex and age at death are given after Karin Mark personal archive (TLU AI, F18); radiocarbon dates of from Kriiska *et al.* (2007), Lõugas *et al.* (2007) and Rasmussen *et al*. (2015).

- Sope I, female adult, (UBA-29064; 3969±32, 2575–2349 calBCE).
- Sope II female adult, (Poz-10827; 4090±35BP, 2870–2490 calBCE)

Kunila, Estonia

Kunila burial site is situated in Central Estonia, 4 km south-west of Puurmani on the western side of a small drumlin on Jaaniantsu Hill. The burial site was discovered in 1938, when stone axe and loose human bones were found during gravel mining. During the archaeological excavations in 1948 skeletal remains of two individuals were uncovered (Jaanits 1948; AI 3723). Kunila burials had grave goods: in connection to Kunila I a stone adze and a battle-axe were found; in connection to Kunila II burial an adze of white flint and a grinding stone were obtained. The burials are attributed to Corded Ware Culture (Jaanits *et al.* 1982, 106–109).

The biological sex and age at death are given after Karin Mark personal archive (TLU AI, F18); radiocarbon date from Kriiska *et al.* (2007) and Lõugas *et al.* (2007).

- Kunila I, male adult. No direct radiocarbon date.
- Kunila II, male adult (Poz-10825;3960±40BP, 2580–2340 calBCE)

Valma, Estonia

Valma is located in Central Estonia on the north-western shore of Lake Võrtsjärv, at the village Valma. The site was discovered in 1948, archaeological excavations lead by Lembit Jaanits were conducted in 1949, 1950, and 1953–1955. Although the majority of the settlement area was studied no other constructions than c. 10 hearths were found (Jaanits 1955, 188). These allowed concluding that three to five contemporaneous dwellings must have been part of the settlement (Jaanits 1965, 16). Also, six hearths with stone packing were found on the upper horizon of the cultural layer; these could either belong to the Typical Combed Ware or the Corded Ware Culture (Jaanits 1965, 16) or even to the Late Iron Age. The majority of the find material is Typical Combed Ware sherds (Jaanits 1955, 188; Jaanits 1959, 66–68, Таблица III, IV, V; Jaanits 1965, 19 Abb. 8), but shards of Late Combed Ware and Corded Ware were also present. Also small stone tools from local flint were found (Jaanits 1955, 188; Jaanits 1959, 64, Таблица I, 74–75, Таблица XI, XII; Jaanits 1965, 29 Abb. 9), and various kinds of adzes (Jaanits 1955, 189; Jaanits 1965, 21 Abb. 10).

From the periphery of the settlement area (NW part) two individuals – an adult male (III) and a young female (II) – were found (Tõrv 2016). These were adorned with grave goods (Jaanits 1959, 39–40; Jaanits 1965, 17–18). Another grave with the remains of a child (I) in a depth of 115 cm from the topsoil was found on the SE part of the settlement. In this case only the skull and some other bones (Jaanits 1959, 39; Jaanits 1965, 18; Jaanits *et al.* 1982, 68) were detected.

Due to the poor collagen preservation none of the three graves are dated (Tõrv 2016). Grave descriptions given after Tõrv (2016).

- Valma I, a child; partially preserved; without grave goods. No direct radiocarbon date.
- Valma II, an adult male; buried on back with both upper and lower limbs in extension; grave goods present. Probable collective burial, placed into the same grave with individual no. III. No direct radiocarbon date.
- Valma III, a young woman; buried on back with both upper and lower limbs in extension; grave goods present. Probable collective burial, placed into the same grave with individual no. II. No direct radiocarbon date.

<u>Kääpa, Estonia</u>

Kääpa is a settlement site located on the left bank of the Võhandu River, c. 5–10 km north-east of the Tamula settlement and burial site. The site was discovered in 1958 during the construction work of a bridge (Aun 1963, 9), and excavated in 1959–1962 and 1974 by Jaanits (Jaanits 1976, 45–48). Similar to Tamula and Akali, the cultural layer at Kääpa is covered with peat, which indicates that during the habitation of the site, the water level at Võhandu River was lower than it is today (Aun 1963, 10; Jaanits 1968, 14–15). The find material is plentiful, being mostly represented by Narva Ware, but also Typical Combed Ware sherds have been found (Aun 1963; Jaanits 1976). During the excavations in 1962, single human bones and cranial fragments were found from Kääpa (Aun 1963, 12).

Kääpa I, an almost complete cranium with maxillary teeth of an adult individual are stored in the Archaeological Research Collections at the Tallinn University (AI 4245). No direct radiocarbon date.

<u>Narva Joaorg, Estonia</u>

Narva Joaorg is located near the present town of Narva on the eastern border of Estonia of the western bank of the Narva River. The site was discovered in 1953 and in 1954 and 1957 Jaanits carried out preliminary surveys that were followed by extensive excavations in 1960 and 1962–1964. Narva Joaorg is a multi-layered and multi-cultural site consisting of three pre-ceramic Mesolithic layers and a Mesolithic/Early Neolithic layer with both Narva Ware and Typical Combed Ware present (Jaanits 1954; Jaanits 1965b, 37–42; Jaanits & Liiva 1973, 158; Jaanits *et al.* 1982, 44). The oldest settlement layer was situated directly above the limestone bedrock. The radiocarbon dates from the Mesolithic layers date the site to c. 6600–4200 cal. BC, being the earliest known human occupation in the Narva-Luga region (Rosentau *et al.* 2013, 927).

The descriptions of graves (AI 4264) are given after Tõrv (2016), whereas all of these comprise of loose, i.e. not fully articulated, human bones. No direct radiocarbon dates are available from human bone due to poor collagen preservation (Tõrv 2016):

- Narva Joaorg I, probable male, adolescent, in the I Mesolithic layer, no grave goods. No direct radiocarbon date.

- Narva Joaorg II, an adult, in the II Mesolithic layer, no grave goods. No direct radiocarbon date.

- Narva Joaorg IV, an adult, in the III Mesolithic layer, grave goods. No direct radiocarbon date.

Biržai, Lithuania

The single burial site is located within the limits of the Biržai town in the northern part of Lithuania. Grave was originally placed at the edge of a steep and clayey bank (elevation up to 53 m a. s. l.) of the river Apaščia, some few hundred meters south from where it meets one of its tributaries – the river Agluona. In the 16th c. the dam was built on the confluence of above-mentioned rivers, creating the artificial lake Širvėna. The placement of the burial site in the landscape is very similar to Benaičiai case as there are valleys of the rivers Apaščia to the east and Agluona to the west as well as a steep slope descending to what used to be the wet grasslands that are flooded at the present.

The grave was partially destroyed during the construction works in 2013 and then rescue excavations took place in 2014 uncovering the single grave dating to the Late Neolithic period (Duderis 2015).

- Biržai 1, 30-35 year old male (Poz-64678; 3955 ± 30 BP, 2570–2350 calBCE)

Donkalnis settlement and burial site

The site comprises of a settlements dating to the Mesolithic, Late Neolithic and Early to Middle Bronze age and burials dated to a Mesolithic and Neolithic periods. It is located in the central north-western part of Lithuania. It is situated on a glacial kame formation (elevation up to 156 m a. s. l.) towering above the marshy northern part of the lake Biržulis where the rivulet Druja flows into it. In some stages of the Stone age the kame may have been an island (Butrimas 2012; Butrimas et al 1985; Kunskas & Butrimas 1985).

After the first melioration of the lake in the 1930's the site became accessible on foot and local residents started exploiting it for gravel quarrying. The site caught archaeologists' attention only in 1979 when a local child told them about human bones being constantly uncovered during gravel extraction. Site was excavated in1981-1983) resulting in the discovery of 7 undisturbed inhumation graves among numerous pottery fragments, flint artefacts and pits. Three out of 7 graves (no. 2-4) were C14 dated to the Middle Mesolithic, Early Neolithic and Late Mesolithic periods, respectively, but the director of the excavations argues that 3 above-mentioned graves together with one more grave (no. 5) belong to the Middle – Late Mesolithic with the rest of them (no. 1, 6-7) dating to the Late Neolithic period (Butrimas 2012). The authors of this article suggest that there are some flaws considering the chronology of Donkalnis graves. These issues are addressed in more detail further in the text. Minimal number of individuals (MIN) determined from the bones collected in the vicinity of the destroyed part of the kame shows that graves of at least 6 more individuals were destroyed during quarrying (Butrimas et al 1985).

- Donkalnis 1, ~20 year old female, no direct dating.
- Donkalnis 4, 50-55 year old male (OxA-5924; 6995 ± 65 BP, 6000–5740 calBCE)
- Donkalnis 5, child (Poz-61589; 7140 ± 40 BP 6075–5920 calBCE)
- Donkalnis 6, 35-40 year old female (Poz-61574; 5770 ± 40 BP, 4720–4530 calBCE)
- Donkalnis 7, ~50 yeaor old male (Poz-61576; 6220 ± 90, 5460–4940 calBCE)

<u>Gyvakarai burial site</u>

The burial site is located in the northern part of Lithuania on the steep gravelly bank (elevation up to 79 m a. s. l.) of the rivulet Žvikė, 500 m to the south from where, in the wet grassland valley, it meets the main stem river Pyvesa.

The site was discovered in 2000 when local residents started digging for gravel in the central part of the gravelly bank. The same year rescue excavations were conducted in the surrounding area of the highly disturbed grave resulting in discovery of a single grave C14 dated to the Late Neolithic (Tebelškis & Jankauskas 2006).

- Gyvakarai 1, 35-40 year old male (Poz-61584, 4030 ± 30 BP, 2620–2470 calBCE)

<u>Kretuonas settlement and burial site</u>

The Neolithic – Bronze Age settlement and the Neolithic burial site is located in the eastern part of Lithuania. It is situated on a small sandy height (elevation up to 147 m a. s. l.) edged between the lake Kretuonas to the west and marshy remains of the nameless grown up lake to the east (Girininkas et al 1985). Surroundings of the lake Kretuonas are rich in a variety of settlements and burial places dating from the Stone to the Early Middle ages.

The site was discovered in 1978 when the area was being planted with forest. The same year archaeological excavations were started and continued for thirteen years (1978-1980, 1982-1985, 1991, 1994-1997, 1999, 2001). In 1980, six undisturbed graves dating to the Early – Middle Neolithic periods were uncovered in the low-lying and intermittently flooded periphery of dwelling area. Uncovered graves themselves and their placement in the surrounding landscape arguably show signs of unusual burials.

- Kretuonas 1, 20-25 year old female (OxA-5935, 5350 ± 130 BP, 4460–3820 calBCE)
- Kretuonas 2, 14-16 year old juvenile, no direct dating.
- Kretuonas 3, 50-55 year old male (OxA-5926, 5580 ± 65 BP, 4550–4330 calBCE)
- Kretuonas 4, >55 year old female, no direct dating.
- Kretuonas 5, 25-30 year old male (Poz-64677, 5540 ± 35 BP, 4450–4340 calBCE)

- Kretuonas 6, infant, no direct dating.

Spiginas settlement and burial site

The Neolithic – Bronze age settlement and the Mesolithic – Neolithic burial site is located in the central north-western part of Lithuania. The settlement is situated on a terrace (elevation up to 156 m a. s. l.) in the centre of which is a glacial kame formation (elevation up to 163 m a. s. l.) with a burial site on top of it. In some stages of the Stone Age this terrace and kame may have been an island in what is now a marshy southern part of the lake Biržulis (Butrimas 2012, 1992; Kunskas & Butrimas 1985).

This site is different from the others because it was discovered by professional archaeologists from the very beginning which led to two years of excavations (1985 – 1986). During these excavations 4 graves were discovered and C14 dated to the Middle Mesolithic, Middle Neolithic and Late Neolithic periods (Butrimas 2012).

- Spiginas 1, 35-45 year old male (Poz-61572, 5470 ± 40 BP, 4440–4240 calBCE)
- Spiginas 2, 50-55 year old male (Poz-61573, 3580 ± 60 BP, 2130–1750 calBCE)
- Spiginas 3, female (OxA-5925, 7780±65BP, 6400–6240 calBCE)
- Spiginas 4, 30-35 year old female (Gin-5571, 7470 ± 60 BP, 6440–6230 calBCE)

Plinkaigalis burial site

The burial site is located in the plains of central Lithuania on the eastern bank of the river Šušvė on the outskirts of the Plinkaigalis village, approximately 400 m south-east of an Iron age hill fort and settlement (Kazakevičius 1993). It is a relatively plain area, which is nevertheless distinguished from the surroundings by a low (up to 2 m height) moraine hill of sand and gravel (elevation up to 94 m a. s. l.).

The burial site was discovered in 1975 when local residents started digging for gravel in the western part of the hill. The same year site was granted a legal protection with archaeological excavations carried out for eight straight years in a row (1977-1984). During the eight years of fieldwork a total of 373 graves (364 inhumation and 9 cremation graves) with all but two of them dating to 3rd to 8th c. AD were uncovered (Kazakevičius 1993). The two exceptional graves (no. 241, 242) were uncovered in the northern part of the burial site and C14 dated to the Late Neolithic (Ramsey et al 2000).

- Plinkaigalis 241, 50-55 year old female (OxA-5928, 4030 ± 55 BP, 2860–2410 calBCE)
- Plinkaigalis 242, >40 year old female (OxA-5936, 4280 ± 75 BP, 3260–2630 calBCE)

Turlojiškė archaeological complex, Lithuania

The Turlojiškė archaeological complex is a group of settlement, burial, sacrificial, and other archaeological sites in a large, peaty area on the right bank of the river Kirsna in south-western part of Lithuania. The relief of this area is almost level, slightly undulating in places, with elevated areas in the northern and southern parts. The river Kirsna is in the western part of the area, the small Turlojiškė forest in the east, the grove Gojus located in the north on the grounds of the Jakimavičius family farmstead, and level cultivated fields in the south (Merkevičius 2012). The first written record about archaeological finds from the area reached us from 1930 (Lietuvos Aidas 1930), in 1931 another paper was written on a human skull called „Kirsna man" (Žilinskas 1931), which later turned out to be a skull of 35-40 year old male (Česnys 2001).

A more precise location of the find spot of the aforementioned finds was not known until field surveys and excavations were conducted from 1995 to 2003. During the excavations 6 additional male graves were discovered and some of them were C14 dated to Bronze age (Merkevičius 2012).

- Turlojiske 3, 25-30 year old male (Vs-1188, 2736±60 BP, 1010-800 calBCE)
- Turlojiske 4, 20-25 year old male (Ua-16681, 2590±75 BP, 908-485 calBCE)
- Turlojiske 1999.5, 20-25 year old male.
- Turlojiske 1999.6, 20-25 year old male.
- Turlojiske1996.1, 35-45 year old male (Poz-66904, 2730 ± 30 BP, 930–810 calBCE)
- Turlojiske 1932, 20-30 year old male („Kirsna man") (OxA-5931, 2895 ± 55 BP, 1230–920 calBCE)
- Turlojiske 1948, 25-35 year old male.

Kivutkalns, Latvia

The Ķivutkalns hill-fort and cemetery was located on the island of Dole, on the lower course of the River Daugava, on a sandy spit of land formed by the former shore of the Daugava and the bed of a former river channel that is nowadays hard to distinguish. The Ķivutkalns site was totally excavated under the direction of Jānis Graudonis in 1966 and 1967 in connection with the building of the Riga Hydroelectric Plant.

The site has been considered as the largest Late Bronze Age bronze-working centre in Latvia. One third of the archaeological artefacts found at Kivutkalns hill-fort in the lower Daugava river is related to bronze working (Vasks 2010). The Ķivutkalns was a double monument: according to archaeological evidence, a fortified residential site had been established directly on top of what had originally been a burial site. This in itself is an unusual, even unique case: the establishment of a hill-fort on top of a prehistoric cemetery. Based on ^{14}C dating and artefactual dating, the hill-fort was placed in the 1st millennium BC (Graudonis 1989). Radiocarbon datings of bone samples (by Finnish Museu of Natural History, 2008 and 2011) indicated 2543 to 2576 years BP for animal bones, found in hillfort, and 2475 to 2555 BP for human bones, found in cemetery.

Combining the new animal bone data to old radiocarbon dates of charcoal provides supporting evidence for archaeological consensus date of the hill-fort usage during the first millennium BC. Five human bone collagen ^{14}C datings are surprisingly young and suggest that periods for cemetery and hill-fort usage were overlapping.

The cultural layer, with a thickness of 1.6–3 m protected the cemetery from the harmful effects of the atmosphere and precipitation and in combination with the encasing of the burials in oak log it resulted in an exeptionnaly good preservation of the skeletons. All the burials in the cemetery were preserved (247 inhumations and 21 cremations, Denisova, Gravere, Graudonis 1985).

For this work, all the studied individuals were radiocarbon dated and the results are given below (see also Table 1). Generally, the dates are consistent with the earlier measurements. Full discussion on the dates incorporated with dietary isotopic signals and potential reservoir effects is published elsewhere (Oinonen et al 2017).

- Kivutkalns 19. Male aged 40-50 (Hela-3746, 2403 ± 24 BP, 730-400 calBCE), on the back in an oak log. A bone needle on the breast. 14 stones arranged around burial, white sand strewn below it.
- Kivutkalns 25. Male aged 35-40 (Hela-3738, 2545 ± 30 BP, 800-545 calBCE), on the back in an oak log. 4 stones arranged around burial, white sand strewn below it.
- Kivutkalns 207. Female aged 40-50 (Hela-3743, 2511 ± 30 BP, 790-535 calBCE). in an oak log. White sand strewn below burial. A bone needle on the back.
- Kivutkalns 194. Male aged 30-40 (Hela-3737, 2298 ± 28 BP, 405-230 calBCE), on the back in an oak log. A bone needle on the breast.
- Kivutkalns 209. Male aged 25-33 (Hela-3741 and 3742, 2497 ± 30 and 2556 ± 30 BP, 785-515 and 805-550 calBCE) in an oak log. Stones arranged at the head part of burial. White sand strewn below burial. Both mandible (Hela-3741) and maxilla (Hela-3742) were dated.
- Kivutkalns 215. Disturbed. Female aged 18-22 (Hela-3745, 2462 ± 27 BP, 760-425 calBCE), without any artefacts.
- Kivutkalns 42. Female aged 35-42 (Hela-3740, 2573 ± 30 BP, 810-560 calBCE), possibly in a linden coffin. No artefacts.
- Kivutkalns 222. Male of big stature, aged 60-70 (Hela-3736, 2423 ± 26 BP, 745-400 calBCE), on the back in an oak log. A fragment of bone needle at the left side of the breast. A stone at the head of burial. White sand strewn below burial.
- Kivutkalns 153. Male aged 45-55 (Hela-3744, 2542 ± 29 BP, 800-545 calBCE), without artefacts.

- Kivutkalns 164. Aged 18-25 (Hela-3739, 2385 ± 30 BP, 730-390 calBCE), without artefacts.

Scandinavia

Archaeological finds show a human presence in Denmark and the south Swedish province of Skåne during the Lateglacial, when most of the Scandinavian peninsula still was covered by glaciers (Larsson 1994, Larsson et al. 2002, Knarrström 2004, Fischer et al. 2013). The ensuing Preboreal period saw a rapid colonization over large tracts of lands, with settlements established all along the coasts of Norway and West Sweden (Nordqvist 2000: 182-197, Kindgren 2002, Bjerck 2009, Schmitt et al. 2009, Fuglestvedt 2012, Breivik 2014, Jaksland & Persson 2014), and also some sites known from Eastern and Northern Sweden as well as Northern Finland (Kankaanpää & Rankama 2011, Möller et al. 2012, Hallgren in press). The Early Mesolithic archaeological assemblages differ between the South-West and the North-East, suggesting that groups with contrasting technological traditions entered the Scandinavian peninsula from different directions: One northern route through Finland that brought the post-Swiderian tradition, and a southern route through Denmark that brought the post-Ahrensburgian tradition (Kankaanpää & Rankama 2011, Knutsson & Knutsson 2012, Sørensen et al. 2014). It is also possible that humans crossed the Baltic by boat or on the sea ice of winter. Regional differences in material culture and technological traditions during the subsequent millennia of the Mesolithic (eg. Hallgren 2004, David 2009, Sørensen et al. 2014, Bergsvik & David 2015), may partly be related to patterns that were already established during the colonization process, but may also be a result of later spread of traditions through social networks and/or resettling of groups of hunter-gatherers.

Around 4000 calBCE agriculture was introduced into South Scandinavia, along with a characteristic set of material culture known as the Funnel Beaker Culture (FBC or in the following TRB after the German term *Trichterbecherkultur*) (Price 2000, Fischer 2002, Hallgren 2008, 2011, Sørensen 2014, Andersson et al. 2016). There are a few examples of domesticates that pre-date this event, in the form of carbonised cereal grains, imprints of cereal grains in Mesolithic pottery and bones from domestic animals (Koch 1998 p.49-50, Jennbert 2011, Sjögren 2011, Sørensen 2014), but it is only after 4000 calBCE that evidence of farming and cattle rearing becomes abundant in Denmark and South Sweden. Cattle was not only a source for meat, but was also used for dairy production (Craig et al. 2011, Isaksson & Hallgren 2012, Gron et al. 2015, Andersson et al. 2016). Material culture that can be considered part of the Funnel Beaker tradition also appear in South Norway, but here evidence of agriculture remain elusive or at beast sporadic (Hjelle et al. 2006, Østmo 2007, Hallgren 2008: 245-250, Bergsvik & Østmo 2011, Glørstad 2012, Solheim 2012, Reitan & Persson 2014). In the region of Denmark and South Sweden where agriculture do occur, it was practised along side hunting, gathering and fishing (Price 2000, Fischer 2002, Andersen 2008, Craig et al. 2011, Andersson et al. 2016).

In Southernmost Sweden, Denmark and adjacent Northern Germany pottery was produced locally already during the Mesolithic Ertebølle phase. The introduction of the TRB pottery tradition meant a change in technology and design that can be viewed as sudden or gradual depending on perspective (Koch 1998, Fischer 2002, Andersen 2011, Hartz 2011, Sørensen 2014). In Central Sweden and Southern Norway TRB pottery was the first ceramic tradition to appear, and thus clearly have an origin outside of these regions (Hallgren 2011, Glørstad 2012). The lithic industries tend to show a degree of continuity between the Late Mesolithic and Early Neolithic in most areas (Stafford 1999, Hallgren 2008, Solheim 2012). From a regional perspective, it is possible to distinguish TRB regions with specific designs and traditions that more or less mirror the geographic extent of Late Mesolithic traditions. This is also true on a pan-regional scale, where the Northern limit of the Scandinavian Funnel Beaker Culture coincide with the Northern limit of Late Mesolithic traditions (Hallgren 2003, Hallgren 2008).

The nature of the transition to the Neolithic in Scandinavia has been debated since the birth of Scandinavian archaeology, and the change has variously been put down to migration or internal development (Kristiansen & Fischer 2002). During the last couple of decades two basic models has dominated the Scandinavian archaeology. One model sees the introduction of agriculture as a consequence of interaction, gift giving and intermarriage through social networks that connected foragers and farmers (Fischer 2002, Hallgren 2003, Jennbert 2011). The other model envisions agriculture as brought by migrating farmers seeking new lands (Rowly-Conwy 2004, 2011, Sørensen 2014). The former model put emphasis on the *continuity* between the Late Mesolithic and the Early Neolithic in terms of lithic technology and complex subsistence practices like seal hunting. The latter model put emphasis on elements that show *discontinuity* like new designs of material culture and the introduction of complex new subsistence practices like cultivation and dairy farming.

At the transition between the Early and Middle Neolithic, c. 3300 calBCE, several changes can be seen in the archaeological record of Sweden. In Skåne and Western Central Sweden a large number of megaliths (dolmens, passage graves) were erected, and a new set of pottery and stone tools of new designs were introduced (Malmer 2002, Sjögren 2010, 2011). This material is known as the Middle Neolithic Funnel Beaker Culture. The change seems to be accompanied by a larger reliance on agriculture (Lidén 1995, Welinder 1998, Sjögren 2003).

The development was quite different in Eastern Central Sweden, where the settlement pattern shifted to the coast (Larsson 2009a). All known interior TRB settlements of an agricultural character were abandoned, and coastal sites previously used as seasonal camps for fishing and sealing were turned into more or less permanent settlements (Hallgren 2008, 2009, Larsson 2009a). While there are traces of small scale agriculture at several of these coastal localities (eg. carbonised cereal seeds, cf. Edenmo & Heimdahl 2012, Andersson 2013), the bulk of the subsistence economy seem to have shifted towards marine resources like fish and seal (Segerberg 1999, Storå 2001, Eriksson 2004, Fornander et al. 2008, Olson 2008, Larsson 2009a). The economic change was accompanied by a change in material culture, particularly pottery design (Larsson 2009a). The archaeological assemblages from this phase is known as the Pitted Ware Culture (PWC). It should be emphasised that the change in material culture was gradual, and that the pottery of the first phase of the PWC retained the funnel-beaker shape, with changes mainly confined to the composition of the decoration, and the surface treatment of the vessels (Hallgren 2009, Larsson 2009a, 2009b).

The archaeological terminology with monikers like "Early Neolithic Funnel Beaker Culture", "Middle Neolithic Funnel Beaker Culture", and "Pitted Ware Culture" seem to imply a continuity between the Early and Middle Neolithic TRB, and a discontinuity between the EN TRB and PWC. However, it is important to recognise that this terminology was caused by research historical happen stance during the early 20th centuary (Larsson 2009a, Hallgren 2009, 2012). From the perspective of material culture, there is as much continuity between the EN TRB and the PWC, as between the Early and Middle Neolithic TRB.

The phase of the Pitted Ware Culture that display a clear continuity with the preceding EN TRB, the Fagervik II stage, is primarily known from the former EN TRB areas of mainland and coastal archipelagos of Eastern Central Sweden (Meinander 1957, Segerberg 1999: 82). The early PWC also appear in the regions immediately to the north of the EN TRB area, regions that were occupied by aceramic hunter-gatherers during the preceding phase (the latter groups are sometimes included under the term Slate Culture, cf. Brøgger 1906, Hallgren 2009, 2012). This may be a territorial expansion of the EN TRB turning PWC, or local hunter-gatherers finally adopting the ceramic technology of their neighbours. An indication that the latter scenario may be right is the fact that there is a simultaneous transfer of technology going in the other direction: the use of the raw material slate for the production of polished arrow and spear points that become an important part of the PWC (Taffinder 1998, Hallgren 2009).

During the following phases (Fagervik III, IV etc) the Pitted Ware phenomen spread over a larger area (Browall 1991), including the Baltic islands of Öland and Gotland (Sweden) and Åland (Finland). While the former two islands have traces of a TRB presence during the Early Neolithic, the Åland island had for millennia been settled by groups of hunter-gatherers of the Comb Ware tradition (Stenbäck 2003, Hallgren 2004). Stylistic borrowings from the Comb Ware tradition can be traced already in the EN TRB of Eastern Central Sweden, and the creation of the material culture of the PWC can be seen as the continuation of this process, with a blend of western and eastern ceramic traditions (Timofeev 2000, Hallgren 2009, 2012, Larsson 2009a). During the later phases of the PWC the funnel-beaker shape was abandoned and instead pots were designed with pointed bottoms, akin to East Baltic hunter-gatherer pottery.

From an archaeological point of view then, the Pitted Ware Culture could perhaps be seen as a mix of at least three components: The Early Neolithic Funnel Beaker Culture of Eastern Central Sweden, the Slate Culture of Dalarna and southern Norrland, and the Comb Ware Culture of Åland. It is likely that such a process also had consequences for the genetic composition of the resulting population.

Around 2800 calBCE – at the transition between Middle Neolithic A and Middle Neolithic B according to the Scandinavian terminology – a new set of material culture appear in the archaeological record of South Sweden and Norway, referred to as the Swedish-Norwegian Battle Axe Culture (Malmer 1962, 2002, Larsson 2009a). This is a regional version of the pan-European Corded Ware Culture (CWC). The Swedish CWC is represented by graves and more rarely settlement sites throughout South and Central Sweden, with a northern limit at the 60th parallell North. In the south Swedish province Skåne there are also palisade structures known (Brink 2009). In many regions the archaeological remains of the CWC replace or follow on the preceding MN TRB. This has variously been interpreted as the result of internal development, limited population movements or full scale migrations (Malmer 1962, Larsson 2009a, cf. Kristiansen 1991, Damm 1993). Recent research has stressed the similarities between the early phase of the Swedish CWC and the CWC of Finland, the Baltic Countries and northern Poland (Larsson 2009a p.254-261).

In eastern South and Central Sweden the CWC appear alongside the Pitted Ware Culture (Malmer 2002, Larsson 2009a). While the latter have a clear association with the coast, due to the subsistence focus on fishing and sealing, the settlements and graves from the CWC are often found in the interior, without a direct association with water. The data on the subsistence of the CWC is sparse, but include domesticated animals, cereal crops and wild forest game (Hallgren 2000, Welinder 1998, Malmer 2002, Larsson 2009a).

The northernmost provinces in Sweden with settlements and graves of the traditional CWC are Uppland and Västmanland in eastern Central Sweden. Most of Northern Sweden remained the territory of hunter-gatherers, but there also appear a small number of sites along the coast that contain archaeological material associated with the CWC (Baudou 1992). These sites are of two types, one of which have been interpreted as the result of direct long distance (1500 km) colonization by CWC groups originating in South Scandinavia, the other type show a larger degree of continuity with the local hunter-gatherer traditions, but with with additions of cultivated plants and stylistic or technological borrowings that suggest contact with the CWC tradition.

The former category is best exemplified with a series of sites in Västerbotten, eg. Bjurselet, a settlement where close to 200 flint axes have been found, despite being located some 1500 km north of the nearest flint sources of South Scandinavia (Knutsson 1988, Baudou 1992 p.71-74, Olausson et al. 2012). The lithic reduction done at Bjurselet suggest that the knappers where schooled in the technological tradition of South Scandinavia (Knutsson 1988). The other category is examplified by the sites Hedningahällan in Hälsingland and Bjästamon in Ångermanland (Schierbeck 1994, Holm 2006, Gustafsson & Spång 2007). These settlements contain lithic industries typical of the local hunter-gatherers eg. tools of slate and quartz, but in the case of Hedningahällan also fragmented CWC battle-axes, osteological assemblages dominated by seal and fish, but also finds of carbonised cereal seeds. The pottery is of a regional character, although with some stylistic traits reminiscent of Corded Ware (Larsson & Graner 2010). The human crania from Ölsund, Forsa, Hälsingland discussed in the current paper has been found in the same region as the site Hedningahällan and date to the same phase (Hallgren 1996).

Kanaljorden, Motala, Sweden

Kanaljorden, Motala, is a Mesolithic settlement and ritual complex in the town of Motala, Östergötland, Sweden (Hallgren 2011, Hallgren & Fornander in press). Motala cradles the outlet of the big lake Vättern into the river Motala Ström, which in turn discharge into the Baltic Sea. The site Kanaljorden (Motala parish ancient monument 187) is close to both river (100 m) and lake Vättern (300 m), but is situated on the rim and bottom of a separate wetland basin that constituted a small isolated lake during the time in question. Today the area is a peat bog, and is also covered by recent landfill and development.

The human remains that has been subjected to DNA-analysis where found on a man made 12 x 14 m stone-packing that had been constructed on the bottom of the small lake during the Mesolithic. The stone-packing was completely submerged and covered by at least 0,5 m of water at the time of use. The ritual depositions include human bones, mostly skulls and fragments of skulls of adults (21 finds) but also some stray postcranial bones from adults (10) as well as the bones of one infant. The latter find include bones from all parts of the body. The initial sampling for DNA of the Kanaljorden material was done before to the full osteological analysis to avoid DNA contamination. Each isolated find of a crania/crania fragment with part of the maxilla preserved, was numbered as individuals 1-9 during the sampling process, while the bones of the infant was numbered individual 10. A fragmentary find that was assigned as 11 during sampling, was retracted before analysis as the bones turned out to be non-human (was first believed to be fragments of a child crania). A disarticulated mandible was designated individual 12.

The osteological analysis that were done later calculated the MNI to ten based on the number of occipital bones, nine adults and one infant. This match the preliminary approximation based on the number of maxilla's, although based on different bone elements (Gummesson & Kjellström manuscript).

The DNA analysis of six of the crania and the mandible confirmed that each of these finds represent a unique individual (Haak et al. 2015, Lazaridis et al. 2014). Osteological observations and isotope analysis furthermore show that the mandible do not match any of the three remaining "individuals" from whom no DNA data are available (Eriksson et al. 2016, Gummesson & Kjellström manuscript). Furthermore, considering the result of isotope analysis and overlap of bone elements, one fragmentary skull that lack a maxilla can be recognised as an additional individual, given the designation AA. In all this mean that a total of 12 individuals so far has been identified in the Kanaljorden assemblage (individuals 1-10, 12 and AA).

Two of the skulls were mounted on wooden stakes still embedded in the crania at the time of discovery, indicating that the skulls have been put on display prior to the deposition in to the lake. Beside human bones, the ritual depositions also include artefacts of antler, bone, wood and stone, animal carcasses/bones as well as nuts, mushrooms and berries. The fauna assemblage is dominated by bones from wild boar and brown bear, but also include elk (moose), red deer, roe deer, badger, beaver, pond turtle and pike. The depositions of artefacts include smooth bone points, barbed bone points, a bone point with flint inserts, antler pick axes and scrapers/knives made of wild boar tusk.

Direct dates on 18 human bones range between 7013 ± 76 and 6677 ± 31 BP, disregarding one outlier (7212 ± 109) which could not be confirmed by a duplicate date (6773 ± 30). Dates on animal bones (N=13) and tools made of bone and antler (7) range between 6935 ± 47 and 6611 ± 30 BP. The human samples may be affected by a moderate reservoir effect (Eriksson et al. 2016). The time range indicated by the series of dates correspond to the end of the Middle Mesolithic of Scandinavia.

- Motala 300, ind. 7, skull mounted on wooden stake, 30-50yrs. (Ua-42121, 7013 ± 76 BP, 6016-5739 calBCE)
- Motala 307, ind. AA, adult female, same as Motala 317 and 1913.
- Motala 309, ind. BB, male, >30yrs, poss. same as ind. 6 (Ua-51717, 6836 ± 32 BP, 5781-5650 calBCE)
- Motala 311, adult (Ua-51718, 6965 ± 31 BP, 5971-5751 calBCE)
- Motala 313, adult (Ua-51719, 6758 ± 32 BP, 5716-5626 calBCE)
- Motala 314, ind. BB, poss. same as ind. 6
- Motala 317, ind. AA, adult female, same as Motala 307 and 1913
- Motala 318, skull mounted on wooden stake, adult (Ua-51720, 6770 ± 31 BP, 5719-5631 calBCE)
- Motala 363, ind. 1, adult female (Ua-42116, 6701 ± 64 BP, 5721-5515 calBCE)
- Motala 1913, ind. AA, adult female, skull fragment found inside skull of ind. 1, same as Motala 307 and 317 (Ua-42645, 6735 ± 44 BP, 5722-5564 calBCE)
- Motala 4352, skull fragment with injury from a pointed object, adult >25 yrs (Ua-51721, 6896 ± 31 BP, 5844-5718 calBCE)

Kvärlöv Kalkkälla, Saxtorp, Sweden

The site Kvärlöv Kalkkälla (Saxtorp parish ancient monument 61), Skåne, Sweden is an offering-fen of the Funnel Beaker Culture (TRB), situated in the outskirts of the modern village Kvärlöv (Nilsson & Nilsson 2003). The fen is characterised as a spring mire, and is believed to have been rather shallow with varying water level. The material under consideration here date to the Scandinavian Early Neolithic (4000-3300 calBCE). During the Early Neolithic the spring mire was located on a gentle slope facing a narrow bay of the sea, some 50-100 m away, and 200 m from the mouth of the small river Kvärlövsån.

The Early Neolithic (EN) assemblage was found in a layer of sand mixed with fen peat. The find bearing EN layer has an extent of 350 m^2, which gives a rough estimate of the extent of the wetland at this time (Nilsson & Nilsson 2003, Regnell & Sjögren 2006b p.61-65). The finds include 39 disarticulated human bones (0,7 kg). Three fragmentary crania are designated as numbered individuals 1, 2 and 3 in the osteological report, albeit with some reservation regarding the identification of Individual 3 in relation to Individual 2 (Nilsson & Nilsson 2003 p.291). As the radiocarbon dates from these two finds are significantly different (Test statistic T 7.22, Xi2(.05) 3.84, degrees of freedom 1) they likely represent two different individuals. The remaining human bones may represent the same or additional individual, seven of these have been included in the initial screening for aDNA.

Besides human bones, the spring mire also contained fragmented funnel-beaker pottery, knapped flint, hazel nut shells, raspberry seeds and animal bones. The fauna assemblage is dominated by domesticated species (cattle, sheep/goat and pig) but also include various wild animals as roe deer, red deer and seal. A dagger made of cattle bone has been ^{14}C-dated to the same period as the human remains (Ua-25501 4810±75), while bones from sheep/goat and pig are slightly younger and fall in the beginning of the Scandinavian Middle Neolithic (Ua-25499 4470±60, Ua-25500 4550±60) (Nilsson & Nilsson 2003).

There are two Early Neolithic TRB settlement sites in the immediate vicinity, the site Saxtorp (Saxtorp parish ancient monument 26), just 50 m North of the spring mire, and the settlement site Kvärlöv (Saxtorp parish ancient monument 23) 350 m to the South-East. The Early Neolithic phase at the Saxtorp settlement is represented by one singled ailed house, 19 x 6 m, and associated features and finds. The find material include funnel-beaker pottery, cereal seeds, hazel-nut shells and knapped flint. ^{14}C-dates from features in the house indicate that it was in use during the later phase of the Early Neolithic. The settlement site Kvärlöv date to the first half of the Early Neolithic, and contain an oval post built house, 7,5 x 4,5 m, as well as two graves (skeletons not preserved) and features interpreted as wells or watering pits. The finds include fragmented funnel-beaker pottery, knapped flint, teeth from cattle, cereal seeds and a quernstone (Nilsson & Nilsson 2003, Andersson 2004 p.70-72, Regnell & Sjögren 2006a, Andersson et al. 2016).

- Saxtorp 389, adult <40 yrs.
- Saxtorp 462T, older adult.
- Saxtorp 4815.

- Saxtorp 316_5527_5817
- Saxtorp 5092, ind. 1, 20-30 year old female (Ua-9810, 4760±75 BP; Ua-9811, 4520±80 BP, mean 4648 ± 55 BP, 3631-3140 calBCE)
- Saxtorp 5094, ind. 2, adolescent or young adult female (Ua-9809, 4690 ± 75 BP, 3645-3196 calBCE)
- Saxtorp 5158T, adolescent (Ua-52673, 4686 ± 28 BP, 3625-3371 calBCE)
- Saxtorp 5164, ind. 3, adolescent (Ua-9808, 4975 ± 75 BP, 3945-3647 calBCE)
- Saxtorp 5477, ind.3, same as Saxtorp 5146.
- Saxtorp 5478, same individual as either 5092 or 5094.

Ölsund, Hälsingland, Sweden

The human cranium from Ölsund, Forsa parish, in Hälsingland is a stray find exposed by ditching of wetland forest (Hallgren 1996). The find-spot (Forsa parish ancient monument 416) is below the Stone Age sea level, the crania may be the remains of a drowned individual, or a person buried in the sea. Ölsund is located 20 km from the contemporary settlement site Hedningahällan, with an assemblage that show a mix of local hunter-gatherer tradition and CWC influences (cf. above). The crania belong to an individual between 28 and 45 years of age (Gummesson *manuscript*). Compared to a modern skeleton, the features are robust, but less so than many males from Stone Age Scandinavia. There are some traits that point towards the identification of the cranium as female (*tubera frontalia* and *occipitalia*).

- Olsund, 28-45 y old adult (Ua-2138, 3890±80 BP, 2573-2140 calBCE)

Nortwest Russia

The first indications of settlement in the region of Karelia in the northwest of Russia and southwest of Finland date back to the Mesolithic, with the earliest find of a fishing net, radiocarbon dated to 9310±120 BP (Miettinen et al. 2008).

This region is relevant to the peopling of Scandinavia after the retreat of the glacial ice sheets, as it lies on one of the proposed eastern routes of settlement (Sørensen et al. 2013), which has also been suggested for the introduction of Saami-like groups (Tambets et al. 2004). Odentometric analyses suggested continuity between the Mesolithic population of Yuzhnyy Oleni Ostrov and present-day Saami (Jacobs 1992).

Yuzhnyy Oleni Ostrov, Archangelsk, Russia

The Mesolithic site Yuzhnyy Oleni' Ostrov (*Oleneostrovski' mogilnik* or *Deer Island cemetery*), Onega Lake, Karelia, Russian Federation (61°30'N 35°45'E) was first discovered in the 1920s during quarrying activities, which unfortunately resulted in the destruction of large parts of the graveyard. Archaeological examination and professional excavation of the site by Soviet archaeologists in the 1930s and the

1950s eventually led to the discovery of 177 burials (Gurina 1956), while the original size of the burial ground was estimated to have held up to 500 individuals (O'Shea & Zvelebil 1984). The abundance and diversity of grave goods and various mortuary features render the Yuzhnyy Oleni Ostrov site exceptional among other Mesolithic sites in Europe. The site had first been identified as a Neolithic graveyard, but later reanalysis and radiocarbon dating revealed an age of around 7,700–7,300 uncalibrated years BP (Price & Jacobs 1990, Wood 2006). Skeletal remains and artifacts from this site are currently held at the Kunstkamera Museum, St Petersburg, Russia.

Co-analyzed with new data is the genome-wide data of Uz00-40 and UZOO-77 from this site which has been reported in previous studies (Haak et al. 2015, Mathieson et al. 2015).

- UzOO77, female, 7,450-6,950 calBP, layer date based on associated individuals from the graveyard (Price & Jacobs 1990)

Popovo, Archangelsk, Russia

The Mesolithic site is located on the bank of the Kinema River, in the Archangelsk region (64°32′N 40°32′E). The dates obtained for this site range between 9,000–9,500 BP and 7,500–8,000 BP (Oshibkina 1999) and are expected to be revised to younger dates due to freshwater reservoir effects.

- Popovo2, male.

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Supplementary Information Section 2
Supplementary Methods: Screening of samples

Sampling and DNA extraction

Sampling was performed in the cleanroom facilities at the Institute for Archeological Sciences in Tübingen for the Eastern Baltic material, at the Australian Centre for Ancient DNA for the Popovo sample, at the cleanroom facilities of the Max Planck Institute for the Science of Human History, Jena, for the sample from Olsund and Uzhni/Yuzhny Oleni Ostrov, and in the ancient DNA laboratory of the Archaeological Research Laboratory, Stockholm for the remaining Swedish material. The human remains were treated with ultraviolet (UV) light from all sides for 10 min to reduce surface DNA contamination. Teeth were sawed transversally at the border of root and crown before sampling dentine powder from the inside of the crown with a sterile dentistry drill. Bone powder was taken from the inner parts of the bones with a sterile dentistry drill after removing the surface layer of bone.
Between 30 and 200 mg powder were used for each DNA extraction (Supplementary Data 1, column M1). The extraction was performed following a modified protocol[1] resulting in 100µl of DNA extract for each sample. Negative controls were taken along for each extraction setup.

Library preparation and targeted enrichment of human mtDNA

Double-stranded next-generation sequencing libraries were prepared from an aliquot of extract following a protocol established for ancient DNA[2]. Negative controls were taken along for each library preparation setup. Some DNA extracts showed evidence of inhibition of enzymatic reactions, possibly due to the presence of humic acids or chemicals (glue or hardener) used for bone treatment[3]. To overcome inhibition, library preparation was repeated for samples that had a low DNA yield after initial library preparation or that had abnormal extracts (e.g. dark colouring, floating particles etc.) using around ten-fold less extract to dilute potential inhibiting factors. Libraries were then barcoded with sample specific index sequence combinations for later sequencing[4].
The sample Olsund was converted into three libraries using uracil–DNA–glycosylase (UDG)-half treatment[5], and was not enriched for mtDNA. The mtDNA haplogroup and mtDNA contamination reported for this sample was determined from the nuclear capture data.
Libraries were enriched for human mitochondrial DNA[6] pooling at most five different sample libraries into one capture pool.

Sequencing

Libraries and mtDNA enriched library pools were quantified on an Agilent 2100 Bioanalyzer DNA 1000 chip and pooled at equimolar concentration. Libraries not enriched for human mtDNA were shotgun sequenced to determine the percentage of endogenous human DNA in every DNA library and assign the genetic sex of individuals[7]. Libraries enriched for mtDNA were sequenced separately to allow for reconstruction of the mitochondrial genome of each individual and estimation of modern mitochondrial contamination. Library pools were sequenced according to the manufacturer's protocols on an Illumina HiSeq2500 at the department of Medical Genetics at the University of Tübingen for 2 x 101 + 8 +8 cycles to a depth of ~1.5 million reads per sample.

Data processing

After demultiplexing, resulting sequencing reads were processed using a computational pipeline developed for aDNA[8] that merges paired-end reads (default parameters) and mapping of reads against a user-specified reference genome. Between 326 and 10,039,616 shotgun sequenced reads (Supplementary Data 1, column N) went into mapping with BWA (v0.6.1)[9] against UCSC genome browser's human genome reference GRCh37/hg19. For mtDNA capture data between 375 and 7,454,704 reads (Supplementary Data 1, column Q) went into mapping against the human mtDNA reference rCRS[10] using the circular mapper implemented in the pipeline[8]. The low number of reads mapping for Spiginas3 and Motala313 indicated a failure of reagents during library preparation.

The proportion of endogenous human DNA in shotgun sequencing ranged from 0.00% to 59.6% (Supplementary Data 1, column O). Genetic sex could confidently be determined for 55 individuals[11] (Supplementary Data 1, column U).

The mtDNA reconstruction and contamination estimation was performed by an iterative likelihood-based approach, taking into account that the consensus mtDNA sequence should be reconstructed from molecules that originate from a single individual and that show characteristics of aDNA[12]. Complete mitochondrial genomes (covered at least 85%) could be reconstructed for 61 individuals and less than 5% mitochondrial contamination (Supplementary Data1, column S). For these, the percentage of deamination at the molecule ends exceeded 20%, a characteristic of authentic ancient DNA[13] (Supplementary Data1, column T).

The screening procedure of the sample from site Popovo, Russia was previously described in Haak et al. 2015 and Mathieson et al. 2015.

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Supplementary Information Section 3
Y chromosomal haplogroup analysis

We were able to determine the Y chromosomal haplogroup by examining a set of diagnostic positions on chromosome Y using the ISOGG database (http://isogg.org/, accessed in 2016 March). In order to perform this analysis, we restricted our analysis to only include reads with a mapping quality higher than 30. Afterwards, we determined the haplogroups by identifying the most derived Y chromosomal SNP in our individual.

Spiginas1 could be assigned as **I2a1a2a1a** based on L233:G→A (2x). This individual also has one upstream mutations for haplogroup I2a1a2a (L1286: G→A at 1x) and one mutation for I2a1 (PF4004: T→C at 1x) and I2a (L460: A→C at 1x).

Kretuonas2 has a derived allele at I2a1b1:C→T, however only with coverage of 1x. Due to missing significance at that position we are not confident in this assignment. We were however able to find multiple upstream mutations assigning this individual to I2a1b (CTS176, CTS1293, CTS1802, CTS5375, CTS7218, and S2702). We are confident that the placement of this sample in Y chromosomal haplogroup **I2a1b** is correct.

Gyvakarai1 could be assigned as **R1a1a1b** based on S441:G→A (6x) and S224:C→T (3x). This individual also has two upstream mutations for haplogroup R1a1a1 (M417 and Page7) and multiple mutations for R1a1a (M515, M198, L168, M512, and L449) and R1a1 (PF6234, M459, and M448). We are confident that the placement of this sample in Y chromosomal haplogroup R1a1a1b is correct.

Kunila2 has a derived allele at R1a1a1b:C→T, however only with coverage of 1x. Due to missing significance at that position we are not confident in this assignment. We were able to find one upstream mutation assigning this individual to **R1a1a1** (Page7: C→T at 1x), two mutations assigning this individual to R1a1a (M198:C→T at 2x and M512:C→T at 1x) and one mutation to R1a1 (PF6234: C→T at 1x).

Spiginas2 could be assigned as **R1a1a1b** based on S441:G→A (3x). This individual also has multiple upstream mutations for haplogroup R1a1a (M515, L168, M512, M514, L449), R1a1 (PF6234 and L120) and R1a (L63 and L146).

Olsund could be assigned as **R1a1a1b** based on S441:G→A (3x). This individual also has multiple upstream mutations for haplogroup R1a1a (M515, L168 and L449), R1a1 (M459) and R1a (L63 and PF6175).

Turlojiske3 could be assigned as R1a1a1b based on S441:G→A (1x). This individual also has one upstream mutation for haplogroup R1a1a (L168:A→G at 1x), R1a1 (PF6234:C→T at 2x) and R1a (L62 and L63).

Kivutkalns19 could be assigned as **R1a1a1b** based on S441:G→A (4x) and S224:C→T (1x). This individual also has two upstream mutations for haplogroup R1a1a1 (M417 and Page7) and two mutations for R1a1a (M515 and L449) and R1a1 (PF6234 and M459). We are confident that the placement of this sample in Y chromosomal haplogroup R1a1a1b is correct.

Kivutkalns25 could be assigned as **R1a1a1b** based on S441:G→A (3x). This individual also has one upstream mutation for haplogroup R1a1a1 (M417) and two mutations for R1a1a (M515 and L449) and R1a1 (M516 and M459). We are confident that the placement of this sample in Y chromosomal haplogroup R1a1a1b is correct.

Kivutkalns194 has a derived allele at **R1a1a**-L168:A→G. We were able to find one upstream mutation assigning this individual to R1a (L62:A→G at 2x) and one mutation assigning this individual to R1 (P286: C→T at 2x).

Kivutkalns209 has a derived allele at R1a1a1-Page7:C→T, however only with coverage of 1x. Therefore we are not convinced that this represents the truth assigning this individual to R1a1a1, due to missing significance at that position. We were however able to find two upstream mutation assigning this individual to R1a1a (M515: T→A at 1x, L168:A→G at 4x) and multiple mutations assigning this individual to R1a1 (PF6234, L120 and M459). We are confident that the placement of this sample in Y chromosomal haplogroup **R1a1a** is correct.

Kivutkalns222 has a derived allele at R1a1a1-M417:G→A, however only with coverage of 1x. Therefore we are not convinced that this represents the truth assigning this individual to R1a1a1, due to missing significance at that position. We were able to find one upstream mutation assigning this individual to R1a1a (M512: C→T at 1x), one mutation assigning this individual to R1a1 (M459:A→G at 1x) and one mutation to R1a (L62: A→G at 4x) and are confident with an assignment to **R1a1**.

Due to low coverage no assignment could be made for Popovo2.