

# Manual for Sondovač 0.95 beta

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**Sondovač**<sup>1</sup> is a script to create orthologous low-copy nuclear probes from transcriptome and genome skim data for target enrichment (Schmickl et al., 2016). See <https://github.com/V-Z/sondovac/wiki>.

## Abstract

Phylogenetics benefits from using a large number of putatively independent nuclear loci and the combination with other sources of information, such as the plastid and mitochondrial genome. Selecting such orthologous low-copy nuclear (LCN) loci is still a challenge for non-model organisms. In recently published phylogenies based on target enrichment of several hundred LCN genes, these loci were selected from transcriptomes, genomes, gene expression studies, the literature, or a combination of these sources. Automated bioinformatic pipelines for the selection of LCN genes are, however, largely absent. We created a user-friendly, automated and interactive script named Sondovač to design LCN loci by a comparison between transcriptome and genome skim data. The script is licensed under open-source license GPL v.3 allowing further modifications. It runs on major Linux distributions and Mac OS X. Strong bioinformatics skills and access to high-performance computer clusters are not required; Sondovač runs on a standard desktop computer equipped with modern CPU like Intel i5 or i7.

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<sup>1</sup>English pronunciation is "Sondovach". The word is Czech neologism meaning something like "The Prober" or "The Probe Maker".

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**Sondovač** is a script to create orthologous low-copy nuclear probes from transcriptome and genome skim data for target enrichment (Schmickl et al., 2016). For information and download see <https://github.com/V-Z/sondovac/wiki>.

# 1 Introduction

High-throughput sequencing (HTS) has the potential to greatly increase the amount of phylogenetically informative signal in molecular datasets (Parks et al., 2009, 2012) and overcome difficulties in phylogenetic reconstructions, such as polytomies and low support values, that are often the result of using only a small fraction of the genome. However, HTS also “opens the era of real incongruence” (Jeffroy et al., 2006), and even massive amounts of sequence data do not always result in strongly resolved phylogenies (Pyron, 2015).

Currently, target enrichment (sequence capture) of hundreds of loci is becoming increasingly popular in phylogenetics. In animal phylogenomics non-exonic or partly exonic ultraconserved elements and their quite variable flanking regions are often utilized (e.g. Faircloth et al., 2012; Hedtke et al., 2013; Smith et al., 2014). For plant phylogenetics, low-copy nuclear (LCN) genes are targeted (Mandel et al., 2014; Weitemier et al., 2014; Grover et al., 2015; Heyduk et al., 2015; Mandel et al., 2015; Nicholls et al., 2015; Stephens et al., 2015a,b) due to the paucity of ultraconserved nuclear sequences (Reneker et al., 2012). Target sequencing strategies for plant nuclear genomes are largely lineage-specific, requiring the de novo design of target enrichment probes. Chamala et al. (2015) recently introduced a pipeline for phylogenetic marker development in angiosperms using transcriptomes, and they obtained several hundred putative LCN genes that can be utilized at three phylogenetic levels (genus, family, order); however empirical evidence for the phylogenetic utility of these loci was not demonstrated. Alternative phylogenetic marker developments, also utilizing transcriptomes (Pillon et al., 2014; Rothfels et al., 2013; Tonnabel et al., 2014), resulted in a much smaller number (up to 20) of mainly LCN loci, but these loci were evaluated with PCR in the empirical datasets, not target enrichment. In recently published phylogenies based on target enrichment of several hundred LCN genes these loci were selected from transcriptomes, gene expression studies, the literature, or a combination of these sources (Mandel et al., 2014; Grover et al., 2015; Heyduk et al., 2015; Mandel et al., 2015; Nicholls et al., 2015; Stephens et al., 2015a,b). Weitemier et al. (2014) designed LCN probes for target enrichment based on a combination of transcriptome and genome data. The limitation of this probe design pipeline is that (draft) genomes are still infrequent, especially for non-model species, and are costly to generate. This limitation also applies to the approach of de Sousa et al. (2014), who selected 50 LCN loci from a genomic source and amplified them using target enrichment. Except for Chamala et al. (2015), who offer a user-friendly but empirically untested probe design pipeline, and Weitemier et al. (2014), whose Hyb-Seq pipeline is designed for more advanced users, no automated probe design pipeline for LCN genes is currently available.

In this study (Schmickl et al., 2016) we developed a novel probe design pipeline for targeting orthologous LCN loci for phylogenetic reconstruction by using genome skim and transcriptome data. In particular, genome skim data of one accession of the studied plant group were combined with a congeneric transcriptome from the 1000 Plants (1KP) initiative (<http://onekp.com/>). We implemented our software workflow in the user-friendly, automated and interactive BASH script Sondovač, which allows a straightforward design of LCN probes also for users with limited bioinformatics skills.

Sondovač workflow is divided into three parts (see details at page 5 and Figure 1):

1. Raw input data are analyzed by `sondovac_part_a.sh`.
2. Obtained sequences are assembled by Geneious manually by user.
3. Final probes are produced by `sondovac_part_b.sh`.

## 1.1 Pipeline – how the data are processed

A transcriptome assembly and paired-end genome skim raw data are combined to get hundreds of orthologous LCN loci (Schmickl et al., 2016). Enrichment of multi-copy loci is minimized

by using unique transcripts only, which are obtained by comparing all transcripts and removing those sharing  $\geq 90\%$  sequence similarity using BLAT. Before matching the genome skim data against those unique transcripts, reads of plastid (and mitochondrial) origin are removed with Bowtie 2, SAMtools and bam2fastq utilizing reference sequences. Paired-end reads are subsequently combined with FLASH. These processed reads are matched against the unique transcripts sharing  $\geq 85\%$  sequence similarity with BLAT. Transcripts with  $>1000$  BLAT hits, indicating repetitive elements, and BLAT hits containing masked nucleotides are removed before de novo assembly of the BLAT hits to larger contigs with Geneious, using the medium sensitivity / fast setting. After assembly, only those contigs that comprise exons of a minimum bait length (usually  $\geq 120$  bp in case of probe design for phylogenies) and have a certain minimum total locus length (multiple of the bait length, should not be too short in order to obtain sufficient phylogenetically informative signal; we recommend at least  $\geq 600$  bp) are retained. To ensure that probes do not target multiple similar loci, any probe sequences sharing  $\geq 90\%$  sequence similarity are removed using cd-hit-est, followed by a second filtering step for contigs containing exons of a minimum bait length and totaling minimum loci length (see comments above). To ensure that plastid sequences are absent from the probes, the probe sequences are matched against the plastome reference sharing  $\geq 90\%$  sequence similarity with BLAT and the hits removed from the probe set. The workflow of Sondovač is summarized in the Figure 1. The direction of the workflow is indicated by arrows. Optional removal of reads of mitochondrial origin from the genome skim data is marked by light background. The required input files of Sondovač are highlighted in bold.

For comprehension improvement the steps of Sondovač are consecutively numbered. Sondovač has three parts: two script parts and an intermediate part using Geneious. The workflow is as follows:

**A. sondovac\_part\_a.sh:** Covers steps 1 to 6.

1. Removal of transcripts sharing  $\geq 90\%$  sequence similarity.
2. Removal of reads of plastid origin.
3. Removal of reads of mitochondrial origin (optional).
4. Combination of paired-end reads.
5. Matching of the unique transcripts and the filtered, combined genome skim reads sharing  $\geq 85\%$  sequence similarity.
6. Filtering of BLAT output:
  - 6.1. Choice of transcript or genome skim sequences for further processing.
  - 6.2. Removal of transcripts with  $>1000$  BLAT hits.
  - 6.3. Removal of transcript or genome skim BLAT hits [depending on the selection in (6.1)] containing masked nucleotides.

Input files for **sondovac\_part\_a.sh** are FASTA transcriptome data, FASTQ paired-end genome skim reads and a plastome (and possible as well mitochondriome) reference. The input file for Geneious is the output of **sondovac\_part\_a.sh**.

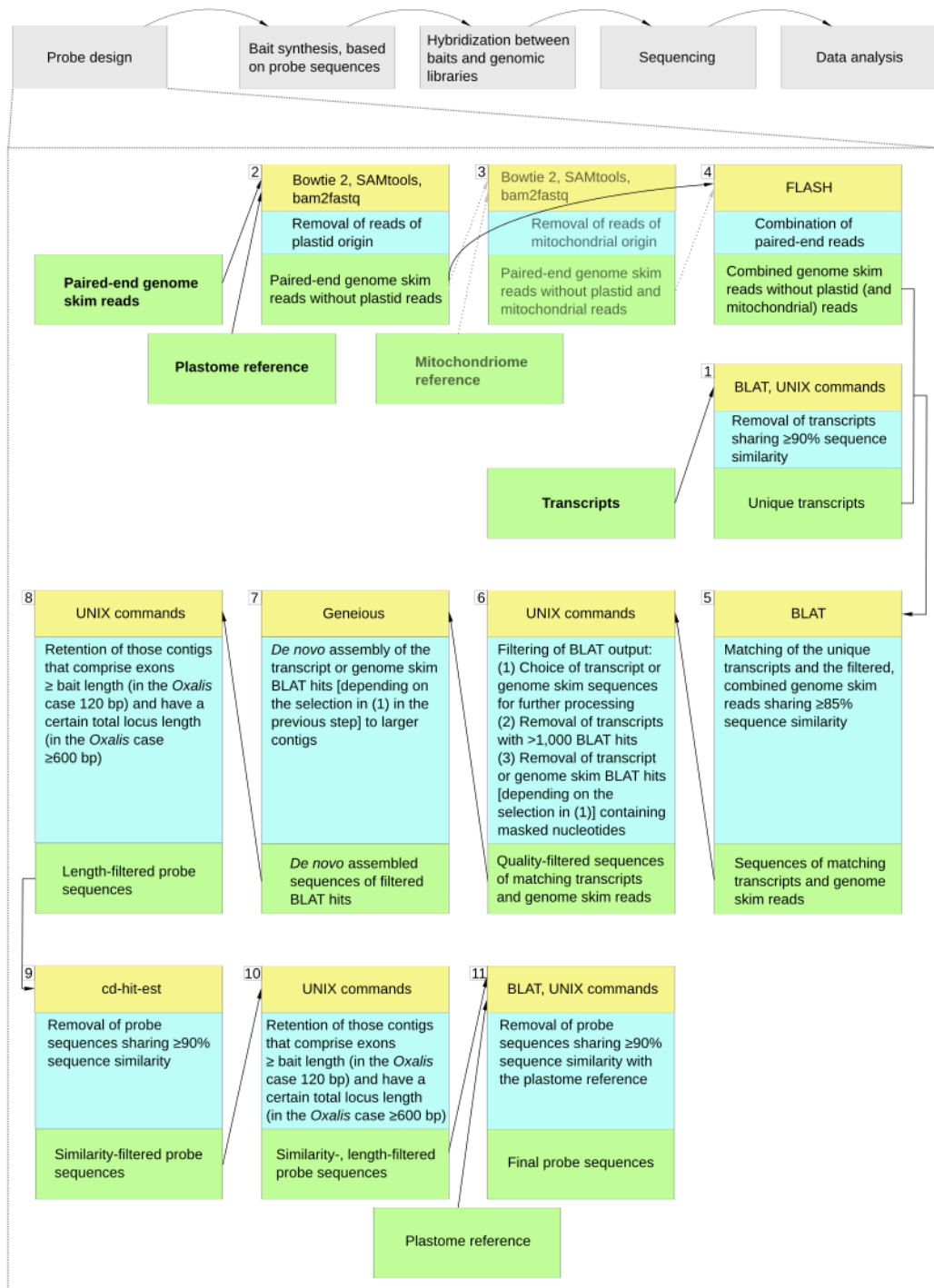
**B. Geneious:** Covers step 7 (see page 14).

7. De novo assembly of the transcript or genome skim BLAT hits [depending on the selection in (6.1)] to larger contigs. Note you need a copy of Geneious for this step.

The output files of Geneious are input files for **sondovac\_part\_b.sh**.

**C. sondovac\_part\_b.sh:** Covers steps 8 to 11.

8. Retention of those contigs that comprise exons  $\geq$  bait length and have a certain total locus length.



**Figure 1:** Workflow of the probe design script Sondovač. An overview on the main steps of Hyb-Seq are given in the top part of the figure; probe design is the first one. Each step of Sondovač is numbered and illustrated by three boxes each: Software is highlighted in yellow, a summary of each step is given in light blue, and input/output of each step is depicted in light green. Optional removal of reads of mitochondrial origin from the genome skim data is marked by decoloration of the text. The required input files of Sondovač are highlighted in bold. The direction of the workflow is indicated by arrows.

9. Removal of probe sequences sharing  $\geq 90\%$  sequence similarity.
10. Retention of those contigs that comprise exons  $\geq$  bait length and have a certain total locus length.
11. Removal of probe sequences sharing  $\geq 90\%$  sequence similarity with the plastome reference.

The output file of `sondovac_part_b.sh` is the final list of probes.

When Sondovač starts, directory `bin` is created in current working directory. Sondovač saves here binaries of required software packages (if they are not available). User can then add this directory to `PATH`, move or delete it afterward.

## 2 Installation of Sondovač

Sondovač is simple BASH script, but it requires some software. The script will check for presence of all required software and if needed, it will offer installation. The most easy way is just to launch the script (see chapter 2.4 at page 12) and let yourselves to be guided through whole needed process.

### 2.1 Requirements to run Sondovač

Sondovač is currently tested on major Linux distributions (in actual versions) openSUSE, Debian, Ubuntu, Linux Mint, Fedora, Centos and Scientific Linux; and on Mac OS X (version 10.10 Yosemite).

In order to run Sondovač you need a UNIX-based operating system (preferably Linux, alternatively Mac OS X) equipped with BASH or compatible shell interpreter (this should be by default available for any Linux distribution, Mac OS X and any other UNIX-based operating system like Solaris, BSD and its variants etc). You should use the current operating system version supported by upstream. Otherwise we will not be able to help you in case of problems. Older operating systems can have different versions of shell and system libraries, which can cause various problems and incompatibilities.

Sondovač is using several scientific software packages (namely bam2fastq, BLAT, Bowtie2, CD-HIT, FASTX toolkit, FLASH, Geneious, htsjdk, libgtextutils and SAMtools – see required versions and links, Table 1), and basic UNIX tools (see below). Sondovač will check if those programs are installed – available in the `PATH` (i.e. if the shell application can locate and launch respective binaries, see also vocabulary at page 17). If you have those packages installed (in current versions, see Table 1), ensure their binaries are in `PATH`. This should not be a problem for basic tools available in any UNIX-based operating system, as basic installation usually contains all needed tools. If you are lacking some of the required tools, the script will notify you, and you will have to install them manually. If this will be needed, check the documentation for your operating system.

If required scientific programs are not installed, Sondovač will offer you installation. You can use precompiled binaries available together with the script or (sometimes) from the web. This is the recommended way. In case you would like to compile required software yourselves, the script will guide you through this process. Anyway, it is recommended only for advanced users, as compilation might sometimes be very tricky. Users of Mac OS X can install those applications also using Homebrew (see <http://brew.sh/>). For compilation you need Apache Ant, GNU G++, GNU GCC, GIT, Java/OpenJDK, libpng developmental files and zlib developmental files. Ensure you have those tools available – they should be readily available for any UNIX-based operating system. Chapters 2.2 and 2.3 give details about requirements and their manual fulfilling. It is mainly reference for more advanced users or users with special needs. For most



users should be fully sufficient to run the script and let it to do this job (see chapter 2.4 at page 19).

Following UNIX tools are required to run Sondovač. They are usually readily available in UNIX systems (but see note for Mac OS X below), so there is usually no need to install them manually. The tools are `awk`, `bc`, `bunzip2`, `cat`, `cp`, `curl` or `wget`, `cut`, `dirname`, `echo`, `egrep`, `cd`, `g++`, `gcc`, `grep`, `gunzip`, `join`, `less`, `lsb_release` or `python` (for Linux), `make`, `mkdir`, `perl`, `pkg-config`, `pwd`, `sed`, `sort`, `tar`, `tr`, `uname`, `uniq`, `unzip`, `wc`. Not all tools are required every time – some are used only during particular actions (e.g. when user decide to compile required software manually). And user usually do not need to bother about them. See also details in following subchapters for some common Linux distributions and Mac OS X.

See below for details about tools required by Sondovač and their manual installation. For most users should be sufficient to be guided by the script to install needed tools automatically.

## 2.2 Installation of required software in Linux

Linux distributions have precise packages management tools (similar, but with more functions, to various app stores known from Android, iOS or recent Mac OS X, MS Windows, etc.), but unfortunately Linux repositories commonly do not contain all needed scientific packages (or not enough recent versions). We recommend pre-compiled binaries of scientific applications available together with the script. If the user for whatever reason wishes to compile the software, the script will guide through that process.

### 2.2.1 openSUSE and SUSE Linux Enterprise (SLE)

SUSE Linux Enterprise (<https://www.suse.com/>) and openSUSE (<https://www.opensuse.org/>) use for package management command `zypper`<sup>2</sup>. The script will check if all required software packages are installed and if not, it will install them. You can do it also manually:

```
1 # Verify installation of basic tools (they are installed in 99.9%):
2 sudo zypper in bash gawk bc coreutils grep less lsb-release perl-base sed wget
3 # Install packages needed for compilation:
4 sudo zypper in gcc-c++ gcc make pkg-config bzip2 gzip tar unzip \
5     patterns-openSUSE-devel_basis libpng12-devel zlib-devel gcc-java \
6     java-1_7_0-openjdk java-1_7_0-openjdk-devel git-core ant
7 # Update installed packages:
8 sudo zypper up
9 # Remove package:
10 sudo zypper rm PACKAGE
11 # Search for package:
12 zypper se PACKAGE/KEYWORD
13 # More information about zypper usage:
14 zypper --help
15 man zypper
16 # Note backslash ("\") means that the code continues on next line
```

Originally, those distributions used only `rpm*` commands (see `rpm --help` and `man rpm` for basic usage).

---

<sup>2</sup>See <https://en.opensuse.org/Zypper> and <https://activedoc.opensuse.org/book/opensuse-start-up/chapter-9-managing-software-with-command-line-tools> for details.



## 2.2.2 Debian, Ubuntu, Linux Mint and derivatives

Debian (<https://www.debian.org/>), Linux Mint (<http://linuxmint.com/>), Ubuntu (<http://www.ubuntu.com/>) and all derived distributions<sup>3</sup> like Kubuntu (<http://www.kubuntu.com/>) use for package management commands `apt-get` (basic) and `aptitude` (front-end for `apt-get`, recommended, not available by default in every DEB distribution). There are more tools<sup>4</sup>, we will describe only basic usage needed for our purpose. The script will check if all required software packages are installed and if not, it will install them. You can do it also manually:

```
1 # Verify installation of basic tools (they are installed in 99.9%):
2 sudo apt-get install bash gawk bc coreutils grep less lsb-release perl-base \
3     sed wget
4 # Install packages needed for compilation:
5 sudo apt-get install build-essential bzip2 gzip tar unzip gcc g++ cpp make \
6     libpng12-dev zlib1g-dev openjdk-7-jre openjdk-7-jdk openjdk-7-source \
7     git ant pkg-config realpath
8 # Update installed packages:
9 sudo apt-get update # Update list of available packages in repositories
10 sudo apt-get upgrade # Actually update installed packages
11 # Remove package:
12 sudo apt-get remove PACKAGE
13 sudo apt-get autoremove # Automatically remove orphaned unneeded packages
14 # Search for package:
15 apt-cache --help # Usage options
16 apt-cache show PACKAGE # Display information about PACKAGE
17 apt-cache search KEYWORD # Search for KEYWORD, including regular expressions
18 # More information about apt-get usage:
19 apt-get --help
20 man apt-get
21 # Interactive command-line package manager
22 sudo aptitude
23 # Help for aptitude
24 aptitude --help
25 man aptitude
26 # Note backslash ("\") means that the code continues on next line
```

Note you can use `aptitude` in similar way as `apt-*` commands (e.g `aptitude instal ...` etc.). For special package operations, there are plenty of `dpkg` commands for advanced management.

## 2.2.3 RedHat, Fedora, Centos, Scientific Linux and derivatives

RedHat (<https://www.redhat.com/>), Fedora (<https://getfedora.org/>; until version 21), Centos (<https://centos.org/>) and Scientific Linux (<https://www.scientificlinux.org/>) and other related distributions<sup>5</sup> use for package management command `yum`<sup>6</sup>. The script will check if all required software packages are installed and if not, it will install them. You can do it also manually:

---

<sup>3</sup>See <http://distrowatch.com/search.php?basedon=Debian> and <http://distrowatch.com/search.php?basedon=Ubuntu> for complete lists.

<sup>4</sup>See <https://wiki.debian.org/PackageManagement> for list of tools and <https://www.debian.org/doc/manuals/debian-reference/ch02.en.html> for exhaustive documentation. Shorter introduction is available at <https://help.ubuntu.com/community/AptGet/Howto> and [http://ubuntuguide.org/wiki/Ubuntu\\_Trusty\\_Packages\\_and\\_Repositories](http://ubuntuguide.org/wiki/Ubuntu_Trusty_Packages_and_Repositories). Ubuntu-specific information at <https://help.ubuntu.com/stable/ubuntu-help/addremove.html>.

<sup>5</sup>See <http://distrowatch.com/search.php?basedon=Fedora> for complete list.

<sup>6</sup>See <http://yum.baseurl.org/> for details.

```

1 # Verify installation of basic tools (they are installed in 99.9%):
2 sudo yum install bash coreutils gawk bc grep less lsb perl sed wget
3 # Install packages needed for compilation:
4 sudo yum install bzip2 gzip pkgconfig unzip gcc gcc-c++ cpp libpng12-devel \
5     make zlib-devel java-1.8.0-openjdk java-1.8.0-openjdk-devel git ant tar
6 # Update installed packages:
7 sudo yum update
8 # Remove package:
9 sudo yum remove PACKAGE
10 # Search for package:
11 yum search PACKAGE/KEYWORD
12 # More information about yum usage:
13 yum --help
14 man yum
15 # Note backslash ("\") means that the code continues on next line

```

Fedora uses since version 22 for package management command `dnf`. It replaces older `yum` and `yum` commands are redirected to `dnf`. Basic usage is same, so that one can just replace `yum` by `dnf` in above examples. Originally, those distributions used only `rpm*` commands (see `rpm --help` and `man rpm` for basic usage).

## 2.3 Installation of required software in Mac OS X

For Mac OS X users, Homebrew (see <http://brew.sh/> and <https://github.com/Homebrew/>) will be installed by the script and it will instal (new software or newer versions) Apache Ant, BASH (the shell interpreter), GNU AWK, GNU coreutils, GNU GCC, git, GNU grep, GNU make, pkg-config, GNU sed and wget. Mac OS X is missing some tools and for others (typically sed, grep or awk) contains too old BSD versions. The script will guide user through the process and if user would wish, it is possible safely and easily remove those tools afterward. Unfortunately, Mac OS X does not have usable build-in package management and it has too old versions of some required tools. Homebrew fills this gap. It is simple command-line installer (similar to package managers known from Linux, BSD or Solaris) of various applications.

Homebrew requires Xcode<sup>7</sup> (set of tools required to compile software) to be installed. Unfortunately, it is not easily universally possible to check if Xcode is installed, so that the script will ask if user wishes to install it. If the user is unsure if Xcode is installed, it is safely possible to answer **Yes** and install it. Manual command to install Xcode is following:

```

1 xcode-select --install
2 # Following error means Xcode has been already installed:
3 xcode-select: note: no developer tools were found at '/Applications/Xcode.app',
4     requesting install. Choose an option in the dialog to download the command
5     line developer tools.
6 # Verify Xcode installation by
7 xcode-select --print-path # Prints installation location of Xcode
8 xcode-select --version # Prints version of Xcode

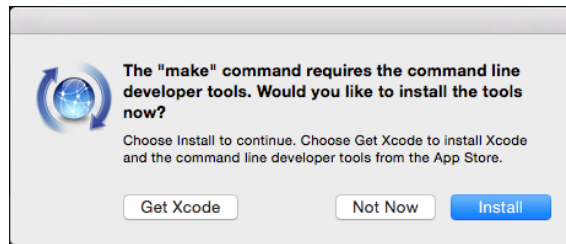
```

If Xcode is not installed yet, user will see windows similar to that on Figure 2, offering installation of Xcode. Select **Install** to continue. After installation, the script will exit and user must start it again.

Script will guide user through all those steps and basic usage of Homebrew. Manual installation of Homebrew is also simple:

---

<sup>7</sup><https://developer.apple.com/xcode/>



**Figure 2:** If user uses command requiring Xcode for first time, system will offer installation of Xcode.

```

1 # Install Homebrew
2 ruby -e "$(curl -fsSL https://raw.githubusercontent.com/Homebrew/install/ \
3   master/install)"
4 # Basic help
5 brew help
6 # Install UNIX tools required by Sondovač
7 brew install coreutils gnu-sed gawk grep bash pkg-config gcc make git ant wget
8 # List of installed packages (brew formulae)
9 brew list
10 # Information about particular formula
11 brew info FORMULA
12 # Search for applications
13 brew search KEYWORD
14 # Update Homebrew
15 brew update
16 # Update all packages installed by Homebrew
17 brew upgrade
18 # Remove Homebrew package (formula)
19 brew uninstall FORMULA
20 # Cleaning after uninstallation
21 brew cleanup
22 # Completely remove Homebrew (after uninstallation of all formulae)
23 ruby -e "$(curl -fsSL https://raw.githubusercontent.com/Homebrew/install/ \
24   master/uninstall)"
25 # Note backslash ("\") means that the code continues on next line

```

Within Homebrew project, there is also scientific section (Homebrew Science, <http://brew.sh/homebrew-science/>) containing plenty of software<sup>8</sup>. When script checks for required scientific packages, it offers several ways to install missing software. Mac OS X users can use also Homebrew. It is the recommended way. If user wish to install the software manually, it is possible to use following commands:

```

1 # Install required scientific packages using Homebrew Science
2 brew install homebrew/science/blat homebrew/science/bowtie2 \
3   homebrew/science/samtools homebrew/science/flash \
4   homebrew/science/fastx_toolkit
5 # Note backslash ("\") means that the code continues on next line

```

Using Homebrew, software will be installed system-wide and Homebrew allows easily check for updates. The only software missing in Homebrew science is [bam2fastq](#) – it is easily installable by another method offered by the script.

<sup>8</sup>See <https://github.com/Homebrew/homebrew-science/wiki/List-of-homebrew-science-formulae> for complete list of available scientific packages.

## 2.4 First launch of Sondovač

Download the latest version from <https://github.com/V-Z/sondovac/releases/> and unpack the archive. You can run Sondovač from any directory. In command line navigate to the directory with the unpacked Sondovač files (see Figure 3):

```
1 cd /path/to/directory_with_sondovac
```

and start it by

```
1 ./sondovac_part_a.sh -h
```

to see basic usage instructions. See chapter 3 at page 19 for more information.

### 2.4.1 Examples

See page 19 for explanation of command line parameters. Basic and the most simple usage (running in interactive mode, see chapter 3 at page 19):

```
1 ./sondovac_part_a.sh -i
```

Specify some of required input files, otherwise run interactively:

```
1 ./sondovac_part_a.sh -i -f input.fa -t reads1.fastq -q reads2.fastq
```

Running in non-interactive automated way (parameter "-n", see chapter 3 at page 19) with example data downloaded from <https://github.com/V-Z/sondovac/wiki/Sample-data>:

```
1 ./sondovac_part_a.sh -f input1_JHCN_Oxalis_corniculata_transcriptome_data.fa \  
2 -c input2_Ricinus_communis_reference_plastid_genome.fsa -m \  
3 input5_Ricinus_communis_reference_mitochondrial_genome.fasta -t \  
4 input3_J12_Oxalis_obtusa_genome_skim_data_R1.fastq -q \  
5 input4_J12_Oxalis_obtusa_genome_skim_data_R2.fastq -n  
6 # Note backslash ("\") means that the code continues on next line
```

Modify parameter "-a", otherwise run interactively:

```
1 ./sondovac_part_a.sh -i -a 300
```

Run in non-interactive mode (parameter "-n", see chapter 3 at page 19) – in such case user must specify all required input files (parameters "-f", "-c", "-m", "-t" and "-q"). Moreover, parameter "-y" is modified:

```
1 ./sondovac_part_a.sh -n -f input.fa -c referencecp.fasta \  
2 -m referencemt.fsa -t reads1.fastq -q reads2.fastq -y 90
```

Modifying parameter "-s". Note interactive mode "-i" is implicit and does not need to be specified explicitly:

```
1 ./sondovac_part_a.sh -s 950
```

We recommend to launch Sondovač at least for first time in an interactive mode, so that the script will verify all requirements and install missing tools when needed. We then recommend to use non-interactive mode for routine usage.

```
script : sondovac_part_a - Konsole
File Edit View Bookmarks Settings Help
vojta@veles:~> cd /home/vojta/dokumenty/botanak/oxalis/south_africa_target_enrichment_genome_skimming/script_probe_design_pipeline/script/
vojta@veles:~/dokumenty/botanak/oxalis/south_africa_target_enrichment_genome_skimming/script_probe_design_pipeline/script> ls -a
.          .info          README
..         .info~        README~
bin        INSTALL      sondovac_functions
geneious_column_separator.pl INSTALL~    sondovac_functions~
geneious_column_separator.pl~ LICENSE    sondovac_part_a.sh
.git       LICENSE~   sondovac_part_a.sh~
.gitignore mac_aliases  sondovac_part_b.sh
.gitignore~ mac_aliases~ sondovac_part_b.sh~
CHANGELOG~ manual      src
CHANGELOG~ pkgs

vojta@veles:~/dokumenty/botanak/oxalis/south_africa_target_enrichment_genome_skimming/script_probe_design_pipeline/script> ./sondovac_part_a.sh -i

#####
#
#   Sondovač is a script to create orthologous low-copy nuclear probes
#   from transcriptome and genome skim data for target enrichment
#
#   Copyright (C) 2015 R. Schmickl, A. Liston, V. Zeisek and others
#
#   When using this script, please, cite Schmickl et al. 2016
#
#####

This is version 0.95 released 2015-11-27.
For newest version check https://github.com/V-Z/sondovac/ or
./sondovac_part_a.sh -u
In case of problems not covered in README for user support see
https://github.com/V-Z/sondovac/
For basic usage see
./sondovac_part_a.sh -h
For detailed usage instructions see README or
./sondovac_part_a.sh -r

This program is free software: you can redistribute it and/or modify it under
the terms of the GNU General Public License as published by the Free Software
Foundation, either version 3 of the License, or (at your option) any later
version. For more information see LICENSE, https://gnu.org/licenses/gpl.html
or "./sondovac_part_a.sh -l".

This program is distributed in the hope that it will be useful, but WITHOUT ANY
WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR
A PARTICULAR PURPOSE. See the GNU General Public License for more details.

#####

This is part A of the pipeline.

This part is for filtering of raw data and their preparation for assembly in
Geneious. Results of Geneious assembly are processed in part B to get the final
list of low-copy nuclear probe sequences. See README and/or manual for details.
Running in interactive mode...

Press any key to continue... (or press Ctrl+C to exit the script).

Continuing...
```

**Figure 3:** Starting terminal and navigating to Sondovač. First look at the terminal (command-line, shell) window, navigation to directory with Sondovač (using command `cd`), listing directory content (command `ls`) and preparing to launch Sondovač (`./sondovac_part_a.sh`).

## 2.5 Help for usage of terminal

If you are not familiar with the usage of command line, see some basic tutorial first. You can try some of those:

- <https://activedoc.opensuse.org/book/opensuse-start-up/chapter-17-shell-basics>
- <https://help.ubuntu.com/community/UsingTheTerminal>
- <https://www.gnu.org/software/bash/manual/> (advanced – full reference manual)
- <http://ubuntuguide.org/>
- <https://www.debian.org/doc/manuals/debian-reference/ch01.en.html>
- [https://en.wikibooks.org/wiki/Guide\\_to\\_Unix](https://en.wikibooks.org/wiki/Guide_to_Unix)
- <http://www.tldp.org/LDP/Bash-Beginners-Guide/html/Bash-Beginners-Guide.html>
- <https://trapa.cz/en/course-linux-command-line-2015>
- [https://docs.fedoraproject.org/en-US/Fedora/22/html/System\\_Administrators\\_Guide](https://docs.fedoraproject.org/en-US/Fedora/22/html/System_Administrators_Guide)

## 2.6 Geneious

For the part (2) user must have Geneious (Kearse et al., 2012). Geneious is a DNA alignment, assembly, and analysis software and one of the most common software platforms used in genomics. It is utilized for de novo assembly in Sondovač. We plan to replace it by some free open-source command line tool in some future release of Sondovač. Visit <http://www.geneious.com/> for download, purchase, installation and usage of Geneious. It is very feature-rich application. The input data are processed (interactively or not) by `sondovac_part_a.sh` and then user must process its output manually by Geneious according instructions below. Output of Geneious is then processed by `sondovac_part_b.sh`, which produce final probe set. Geneious was tested with versions 6, 7 and 8.

## 2.7 Software used by Sondovač

Table 1 lists all software used by Sondovač, including minimal required versions and homepages. As soon as you have recent version of your operating system and you are using automated way of installation of additional software offered by Sondovač, you do not have to worry about this. In case you installed some of required scientific packages manually, ensure you have required minimal version. Following list refers papers and web resources describing methods used by software used by Sondovač:

`sondovac_part_a.sh` requires (and will install) following software packages:

- BLAT
- Bowtie2
- SAMtools
- bam2fastq (will be replaced by Picard in future release)
- FLASH
- FASTX-toolkit

`sondovac_part_b.sh` requires (and will install) following software packages:

**Table 1:** Required software, its versions and homepages. "X" denotes any subversion of particular lineage and "v. >" denotes any version higher then noted. Generally, any current version should usually be fine.

Software	Version	Homepage
Apache Ant	1.9.X	<a href="https://ant.apache.org/">https://ant.apache.org/</a>
bam2fastq	1.1.0	<a href="http://gsl.hudsonalpha.org/information/software/bam2fastq">http://gsl.hudsonalpha.org/information/software/bam2fastq</a>
BASH	v. > 4	<a href="https://gnu.org/software/bash/bash.html">https://gnu.org/software/bash/bash.html</a>
BLAT	v.36	<a href="http://genome.ucsc.edu/FAQ/FAQblat.html">http://genome.ucsc.edu/FAQ/FAQblat.html</a>
Bowtie2	2.2.6	<a href="http://bowtie-bio.sourceforge.net/bowtie2/index.shtml">http://bowtie-bio.sourceforge.net/bowtie2/index.shtml</a>
CD-HIT	4.6	<a href="http://weizhongli-lab.org/cd-hit/">http://weizhongli-lab.org/cd-hit/</a>
FASTX, libgtextutils	0.0.13	<a href="http://hannonlab.cshl.edu/fastx_toolkit/">http://hannonlab.cshl.edu/fastx_toolkit/</a>
FLASH	1.2.11	<a href="http://sourceforge.net/projects/flashpage/">http://sourceforge.net/projects/flashpage/</a>
G++, GCC	v. > 4.2	<a href="http://gcc.gnu.org/">http://gcc.gnu.org/</a>
Geneious	v. > 6.1	<a href="http://www.geneious.com/">http://www.geneious.com/</a>
GIT	v. > 2.0	<a href="http://git-scm.com/">http://git-scm.com/</a>
GNU core utils	8.X	<a href="https://gnu.org/software/coreutils/coreutils.html">https://gnu.org/software/coreutils/coreutils.html</a>
Java/OpenJDK	v. > 7	<a href="https://www.java.com/">https://www.java.com/</a> <a href="http://openjdk.java.net/">http://openjdk.java.net/</a>
libpng	1.6.X	<a href="http://www.libpng.org/">http://www.libpng.org/</a>
SAMtools, htsjdk	1.2	<a href="http://www.htslib.org/">http://www.htslib.org/</a>
Sondovač	0.9	<a href="https://github.com/V-Z/sondovac/wiki">https://github.com/V-Z/sondovac/wiki</a>
zlib	1.2.8	<a href="http://zlib.net/">http://zlib.net/</a>

- CD-HIT
- BLAT

Papers describing the software used by Sondovač:

**BLAT** Kent (2002): BLAT – the BLAST-like alignment tool.

**Bowtie2** Langmead and Salzberg (2012): Fast gapped-read alignment with Bowtie 2.

**CD-HIT** There are several papers describing CD-HIT:

- Li et al. (2001): Clustering of highly homologous sequences to reduce the size of large protein databases.
- Li et al. (2002): Tolerating some redundancy significantly speeds up clustering of large protein databases.
- Li and Godzik (2006): Cd-hit: a fast program for clustering and comparing large sets of protein or nucleotide sequences.
- Fu et al. (2012): CD-HIT: accelerated for clustering the next generation sequencing data.
- Huang et al. (2010): CD-HIT Suite: a web server for clustering and comparing biological sequences.
- Niu et al. (2010): Artificial and natural duplicates in pyrosequencing reads of metagenomic data.
- Li et al. (2012): Ultrafast clustering algorithms for metagenomic sequence analysis.

**FASTX toolkit** Gordon and Hannon (2010): FASTX-Toolkit. FASTQ/A short-reads pre-processing tools.

**FLASH** Magoč and Salzberg (2011): FLASH: fast length adjustment of short reads to improve genome assemblies.



**Geneious** [Kearse et al. \(2012\)](#): Geneious Basic: An integrated and extendable desktop software platform for the organization and analysis of sequence data.

**SAMtools** There are several papers describing SAMtools:

- [Li et al. \(2009\)](#): The Sequence alignment/map (SAM) format and SAMtools.
- [Li \(2011a\)](#): A statistical framework for SNP calling, mutation discovery, association mapping and population genetical parameter estimation from sequencing data.
- [Li \(2011b\)](#): Improving SNP discovery by base alignment quality.

**Sondovač** [Schmickl et al. \(2016\)](#): Phylogenetic marker development for target enrichment from transcriptome and genome skim data: the pipeline and its application in southern African *Oxalis* (Oxalidaceae).

## 2.8 The PATH variable

PATH (\$PATH) is system variable used in every UNIX system. It lists directories (separated by colon ":") where current shell (see also Chapter 2.9 Vocabulary at page 17) searches for binaries (commands). So that user does not have to specify full path to the software (e.g. just `sed` instead of `/usr/bin/sed`). If some software is installed outside standard locations, user must specify full path, even if user is located in same directory as the software (e.g. `./sondovac_part_a.sh` – this is for security reasons). In case there are two commands with same name (e.g. `/bin/somecommand` and `/usr/bin/somecommand`), order of directories in \$PATH matters – the first occurrence is used and any possible latter is ignored (but it uses to be rare case). PATH can be managed using following commands:

```
1 # See the $PATH variable
2 echo $PATH # Sample output is on next line:
3 /home/$USER/bin:/usr/local/bin:/usr/bin:/bin:/opt/bin:/sbin:/usr/sbin
4 # Adding new directory to $PATH
5 export PATH=$PATH:/some/new/directory
6 # Do not use following way - it would overwrite $PATH and there would be only
7 # the new directory (not original content)!
8 export PATH=/some/new/directory # Wrong! Old $PATH is missing and will be lost!
9 # Removing possible duplicate entries in $PATH with regular expressions and awk
10 export PATH="$(echo "$PATH" | awk 'BEGIN{RS=":";}{sub(sprintf("%c$",10), ""); \
11 if(A[$0]){}else{A[$0]=1;printf(((NR==1)?""":"$0)}}')")"
12 echo $PATH # See it after modifications
13 # Note backslash ("\") means that the code continues on next line
```

Sondovač requires certain software to be installed (see Table 1 at page 15) and if some software is missing, script offers installation. By default, Sondovač creates directory `bin` in current working directory and installs there required software. It then temporarily modifies content of \$PATH variable to contain this new directory. Sondovač notes user about it and user can then – if he wishes to keep the newly installed software for later usage – (1) move content of this directory to some better place or (2) add this directory to the \$PATH. This directory can also be safely removed. Permanent modification of \$PATH variable is done by adding line `export PATH=$PATH:/some/new/directory` (same as the above example) to file `~/.bashrc` or `~/.bash_profile` (usage of those files vary little bit among UNIX systems, see manual for your operating system). On Mac OS X, installation of [Homebrew](#) is required. In order to correct functioning of Sondovač, \$PATH is modified to contain directories `/usr/local/opt/coreutils/libexec/gnubin` and `/usr/local/bin` containing new and updated UNIX tools. The first directory must be on beginning as it contains updated versions of basic command line utilities – replacing outdated versions provided with Mac OS X. All those modifications are temporal and used only within Sondovač scripts.

## 2.9 Vocabulary

**Binary** An application in form understandable by the computer, but usually not transferable among operating systems and/or hardware platforms. Binaries in Windows usually have extension \*.exe, in UNIX there use to be no extension.

**BASH** "The command line" – fully featured programming scripting language accessible through terminal of any UNIX-based operating system (any Linux, Mac OS X, Solaris, any variant of BSD and more). BASH scripts usually have extension \*.sh.

**BSD** Group of popular UNIX-based operating systems. See [https://en.wikipedia.org/wiki/Berkeley\\_Software\\_Distribution](https://en.wikipedia.org/wiki/Berkeley_Software_Distribution).

**C** Popular programming language. Source code must be compiled for each operating system. See [https://en.wikipedia.org/wiki/C\\_\(programming\\_language\)](https://en.wikipedia.org/wiki/C_(programming_language)).

**C++** Popular programming language. Source code must be compiled for each operating system. See <https://en.wikipedia.org/wiki/C++>.

**Centos** Popular Linux distribution. Community remake of RedHat Enterprise Linux. See <https://centos.org/>.

**Compilation** "Translation" of software application from the source code (text readable by human programmer) into binary form launchable by the computer. It requires special tools (compilers), and it usually must be done for every operating system and hardware platform.

**Console** See "Shell".

**Debian** One of the oldest and most popular Linux distributions. See <https://www.debian.org/>.

**Fedora** Popular Linux distribution developed together with RedHat Linux as its free community testing platform. See <https://getfedora.org/>.

**GNU** Major project providing free software widely used in many operating systems, see <https://gnu.org/>.

**Homebrew** Tool primarily for Mac OS X (although there is also Linux version available) replacing practically missing package manager for this system. Can be used to install plenty of various applications as well as updating tools already available in Mac OS X. See <http://brew.sh/>.

**Java** Very popular programming language. It requires Java runtime environment to be installed, but the applications are very well transferable among operating systems. See <https://www.java.com/>.

**Library** Pack of software tools and functions used by another applications.

**License** Conditions under which the software is distributed. Can be very restrictive (typically paid software) or permissive (typically free and open-source software).

**Linux** One of the most common variants of UNIX-based operating systems. Linux kernel is used by many developers, so that there are plenty of Linux distributions ("flavors") from various sources (e.g. Ubuntu and derivatives, openSUSE, SLE, Debian, Linux Mint, Fedora, Centos, RedHat etc.). They share many features although on the first look they can look differently. See <https://en.wikipedia.org/wiki/Linux>.

**Linux Mint** Popular Linux distribution based on Debian and Ubuntu. See <http://linuxmint.com/>.

- Mac OS X** Popular operating system produced by Apple. The system kernel is based on UNIX, see <https://www.apple.com/osx/>.
- Open-source** Generally, source code of an application is available together with the application and can be under certain conditions defined in license modified, redistributed etc. See [https://en.wikipedia.org/wiki/Free\\_and\\_open-source\\_software](https://en.wikipedia.org/wiki/Free_and_open-source_software).
- openSUSE** Popular Linux distribution, see <https://www.opensuse.org/>.
- Operating system** Basic system running on your computer – typically MS Windows (not supported by Sondovač, although it might be working), Mac OS X or some Linux distribution (Ubuntu and derivatives, openSUSE, SLE, Debian, Linux Mint, Fedora, Centos, RedHat etc.).
- Package** Software or its part, group of tools, library, etc. Basic unit of software management in most of UNIX systems (mainly Linux, Solaris, BSD, practically missing in Mac OS X). Those systems use to have special applications (command line as well as graphical tools) to easily manage (install, remove, update) software.
- Parameter(s)** Option(s) passed to any function/command line application to modify its usage. Some can be required, some are optional and some can be used only in particular cases. In case of shell applications, parameters are usually given in way like "application -X", "application -parameter", "application -Param SomeValue" and so on. See manual for particular application (e.g. "man application"), in case of Sondovač see page 19.
- PATH** Directories in the computer where the system is looking for installed software (in a UNIX-based system you can view it by the command "echo \$PATH"). If you need to modify it manually, see the documentation for your operating system.
- Perl** Popular interpreted programming language excelling mainly in system tasks working with text. Perl scripts are easily transferable among operating systems. See <https://www.perl.org/>.
- RedHat** Probably the biggest Linux company providing mainly solutions for big companies. See <https://www.redhat.com/>.
- Repository** Internet folder (available through HTTP or FTP) containing software packages for UNIX systems.
- Scientific Linux** Popular Linux distribution. Community remake of RedHat Enterprise Linux. See <https://www.scientificlinux.org/>.
- Script** Software application. It requires an interpreter (application installed on the computer that is able to launch scripts written in a particular language), but the application itself is portable among operating systems and hardware architectures, and it is written in plain text, so that developers can easily modify it. Common examples are Python, Perl or BASH.
- Shell** "The command line" – the interface to interact with software using commands typed into the terminal window (See Figure 3).
- Solaris** Popular (mainly on servers) UNIX-based operating system, now developed by Oracle and including several independent clones. See <http://distrowatch.com/table.php?distribution=solaris>.

**Source code** Human-readable code written in any text editor used to develop any application. Applications written in interpreted languages (BASH, Perl, Python , ...) can be distributed just in form of source code (nothing else is required). Other programming languages (C, C++, ...) require compilation to get fully functional application.

**SUSE Linux Enterprise (SLE)** Large Linux company providing mainly solutions for big companies. See <https://www.suse.com/>.

**Terminal** see "Shell".

**Ubuntu** Popular Linux distribution, see <http://www.ubuntu.com/>. There are plenty of distributions based on Ubuntu. See <http://distrowatch.com/search.php?basedon=Ubuntu>.

**UNIX (UNIX-like, UN\*X, \*nix, ...)** Family of operating systems sharing the same logic, software architecture and plenty of tools. See <https://en.wikipedia.org/wiki/Unix-like> for details.

**Upstream** Developers usually support (e.g. by fixing of bugs) only newer versions of an application. If you use an older version and you encounter problems, no one will probably help you. Moreover, using old versions of software can be a security risk because of security issues fixed in newer versions.

**Variable** Named value storing various information, one of basic part of any programming language, application, operating system.

## 3 Usage of Sondovač

### 3.1 Command line parameters

Sondovač has some parameters useful especially for advanced users, on remote servers, for repeated analysis and so on. We recommend to start with basic interactive usage – script will ask for input files and when needed also for installation of additional software.

```
1 # Go to directory with unpacked Sondovač (in terminal):
2 cd /path/to/directory_with_sondovac
3 # Run sondovac_part_a.sh in basic interactive mode:
4 ./sondovac_part_a.sh -i
5 # Then run Geneious and continue with sondovac_part_b.sh:
6 ./sondovac_part_b.sh -i
```

#### 3.1.1 General parameters

Shared by `sondovac_part_a.sh` as well as `sondovac_part_b.sh`.

**-h, -v** Print help message and exit.

**-u** Check for updates. If there is newer version of Sondovač available on <https://github.com/V-Z/sondovac/releases/> download of newer version will be offered to the user.

**-l** Display LICENSE for license information (this script is licensed under GNU GPL v.3, other software under variable licenses). Exit viewing by pressing the Q key.

**-r** Display README for detailed usage instructions. Exit viewing by pressing the Q key.

**-p** Display INSTALL for detailed installation instructions. Exit viewing by pressing the Q key. See also page 7.

- e Display detailed citation information and exit.
- o Set name of output files. Output files will start with that name. Do not use spaces or special characters - some software can not handle them correctly. Default value (if user does not provide) another name is "output". See below for list of produced output files.
- i Running in interactive mode – script will on-demand ask for required input files, installation of missing software etc. This is recommended default value (the script runs interactively without explicit using option -n).
- n Running in non-interactive mode. User must provide at least required input files (see below). You can use only one of parameters -i or -n (not both of them). If script fails to find some of required software packages, it will exit. This is recommended for batch or repeated analysis, on remote servers and for more advanced users. User must be sure that all required software is installed (see page 7).

### 3.1.2 Input files

Those parameters are required when running in non-interactive mode. The parameters are optional in default interactive mode. Please, use file names without spaces and without special characters.

**-f FILE** Transcriptome input file in FASTA format.

- `sondovac_part_a.sh`

**-c FILE** Plastome reference sequence input file in FASTA format.

- `sondovac_part_a.sh`, `sondovac_part_b.sh`
- Plastome reference sequences from taxa up to the same order of the studied plant group are suitable. See [Straub et al. \(2012\)](#).

**-m FILE** Mitochondriome reference sequence input file in FASTA format (optional).

- `sondovac_part_a.sh`
- This step is facultative, as plant mitochondrial genomes have largely variable sizes and high rearrangement rates.

**-t FILE** Paired-end genome skim input file in FASTQ format (first file).

- `sondovac_part_a.sh`

**-q FILE** Paired-end genome skim input file in FASTQ format (second file).

- `sondovac_part_a.sh`

**-x FILE** Input file in TSV format (output of Geneious assembly).

- `sondovac_part_b.sh`

**-z FILE** Input file in FASTA format (output of Geneious assembly).

- `sondovac_part_b.sh`

### 3.1.3 Optional parameters

See page 5 and Figure 1 for steps referred here. If those parameters are not provided, default values are used and it is not possible to change them any time later (not even in interactive mode).

**-a ###** Read length of paired-end genome skim reads (parameter -M of FLASH, see its manual for details).

- Step 4 of Sondovač, `sondovac_part_a.sh`.
- Ensure to use a certain insert size of the genome skim genomic library in combination with an appropriate read length for sequencing in order to enable merging of the paired-end genome skim reads.
- DEFAULT: 250
- OPTIONS: 125, 150, 250, 300

**-y ##** Sequence similarity between unique transcripts and the filtered, combined genome skim reads (parameter -minIdentity of BLAT, see its manual for details).

- Step 5 of Sondovač, `sondovac_part_a.sh`, and step 11, `sondovac_part_b.sh`.
- Consider the trade-off between probe specificity and number of remaining matching sequences for probe design. Sequence similarity is in percent.
- DEFAULT: 85
- OPTIONS: Integer ranging from 70 to 100

**-s ####** Number of BLAT hits per transcript when matching unique transcripts and the filtered, combined genome skim reads.

- Step 6.2 of Sondovač, `sondovac_part_a.sh`.
- Transcripts with a high number of BLAT hits, indicating repetitive elements, need to be removed from the putative probe sequences.
- DEFAULT: 1000
- OPTIONS: Integer ranging from 100 to 10000

**-b ###** Minimum exon (bait) length.

- Steps 8 and 10 of Sondovač, `sondovac_part_b.sh`.
- The minimum exon length should not fall below the bait length in order to facilitate specific binding between genomic libraries and baits during hybridization.
- DEFAULT: 120 (optimal length for phylogeny).
- OPTIONS: Integer ranging from 120 to 200

**-d 0.##** Sequence similarity between probe sequences (parameter -c of cd-hit-est, see its manual for details).

- Step 9 of Sondovač, `sondovac_part_b.sh`.
- Too similar probe sequences will interact with each other during hybridization and thereby reduce enrichment efficiency.
- DEFAULT: 0.9 (highly recommended).
- OPTIONS: Decimal ranging from 0.85 to 0.95

**-g** Use genome skim sequences instead of transcripts for making the probes.

- Default is usage of transcripts (no parameter).

### 3.2 Input and output files

All names of input files and paths to them must be without spaces and without special characters (some software has difficulties to handle them in such case – it can produce weird errors).

**Important note:** NGS data are big. Sondovač pipeline is relatively long and part A contains several conversions and can (for some time) dozens of GB of disk space. Temporal files without potential usefulness for the user are deleted on the end of pipeline – because those files may be useful for debugging if something would go wrong. For example, input data of [Schmickl et al. \(2016\)](#) has under 4.5 GB, overall output of part A has about 28 GB of which less than half is kept by the pipeline. Part B is very quick and does not consume significant amount of space.

**Script `sondovac_part_a.sh` requires as input files:**

1. Transcriptome input file in FASTA format. **Note:** For technical reasons, names of FASTA sequences in *must* be only unique numbers (no any other characters). Sondovač will check the names and if they are not in appropriate form, copy of this input files with correct names will be created.
2. Plastome reference sequence input file in FASTA format.
3. Paired-end genome skim input file in FASTQ format (two files – forward and reverse reads).
4. OPTIONAL: Mitochondriome reference sequence input file in FASTA format. This file is not required.

**Script `sondovac_part_a.sh` creates the following files:**

0. `*_renamed.fasta` – If needed, copy of transcriptome input file with changed names of FASTA sequences (unique numbers respective to line numbers in original file) will be created. File `*_old_and_new_names.tsv` then contains two columns: **1)** original sequence names as in user provided transcriptome input file and **2)** new sequence names. This might be useful to trace back some sequences/probes.
1. `*_blat_unique_transcripts.psl` – Output of BLAT (removal of transcripts sharing  $\geq 90\%$  sequence similarity).
2. `*_unique_transcripts.fasta` – Unique transcripts in FASTA format.
3. `*_genome_skim_data_no_cp_reads.bam` – SAM converted to BAM (removal of reads of plastid origin).
4. `*_genome_skim_data_no_cp_reads` – Genome skim data without cpDNA reads.
5. `*_genome_skim_data_no_cp_no_mt_reads.bam` – SAM converted to BAM (removal of reads of mitochondrial origin) – only if mitochondriome reference sequence was used.
6. `*_genome_skim_data_no_cp_no_mt_reads` – Genome skim data without mtDNA reads – only if mitochondriome reference sequence was used.
7. `*_combined_reads_co_cp_no_mt_reads` – Combined paired-end genome skim reads.
8. `*_blat_unique_transcripts_versus_genome_skim_data.pslx` – Output of BLAT (matching of the unique transcripts and the filtered, combined genome skim reads sharing  $\geq 85\%$  sequence similarity).
9. `*_blat_unique_transcripts_versus_genome_skim_data.fasta` – Matching sequences in FASTA.



#### 10. \*\_blat\_unique\_transcripts\_versus\_genome\_skim\_data-no\_missing\_fin.fsa – Final FASTA sequences for usage in Geneious.

Files 1-9 are not necessary for further processing by this pipeline, but may be useful for the user. The last file (10) is used as input file for Geneious in the next step. Asterisk (\*) denotes beginning of the output files names specified by the user with parameter -o. If user does not select custom name, default value (output) will be used.

**Geneious** requires as input the last output file of `sondovac_part_a.sh` (file 10: \*\_blat\_unique\_transcripts\_versus\_genome\_skim\_data-no\_missing\_fin.fsa). Output of Geneious are two exported files (see page 24):

1. Final assembled sequences exported as TSV.
2. Final assembled sequences exported as FASTA.

**Script `sondovac_part_b.sh` requires as input files:**

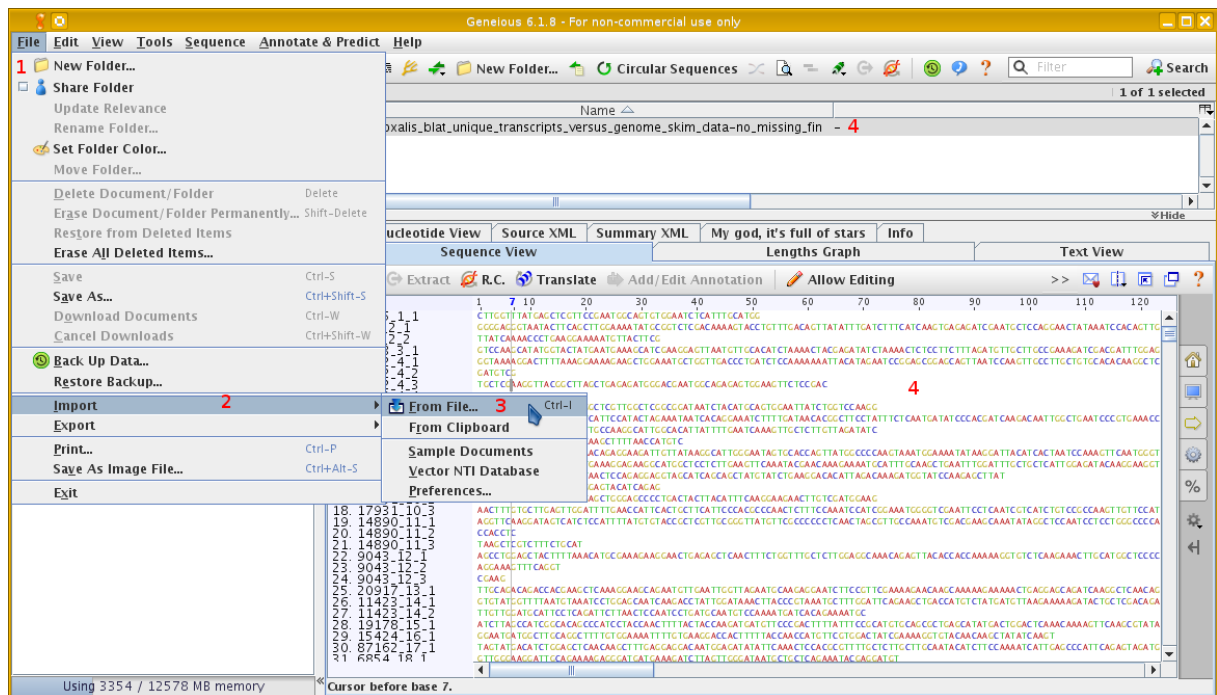
1. Plastome reference sequence input file in FASTA format.
2. Assembled sequences exported from Geneious as TSV.
3. Assembled sequences exported from Geneious as FASTA.

**Script `sondovac_part_b.sh` creates following files:**

1. \*\_prelim\_probe\_seq.fasta – Preliminary probe sequences.
2. \*\_similarity\_test.fasta – Contigs that comprise exons  $\geq$  bait length and have a certain total locus length.
3. \*\_target\_enrichment\_probe\_sequences.fasta – Probes in FASTA.
4. \*\_target\_enrichment\_probe\_sequences\_final.pslx – Final probes ready for bait synthesis.

Asterisk (\*) denotes beginning of the output files names specified by the user with parameter -o. If user does not select custom name, default value (output) will be used. By default, output files are created in same directory from which Sondovač was launched. Output files can be saved in custom directory by specifying output directory together with parameter -o:

```
1 # Find current directory (e.g. /home/user):
2 pwd
3 # Launching Sondovač located in directory /home/user/sondovac
4 # and save output to e.g. desktop (/home/user/Desktop):
5 ./sondovac/sondovac_part_a.sh -o Desktop/MyFile
6 # Sondovač will save software (if needed) in "bin" directory
7 # located in directory from which it was launched, see it:
8 ls bin/*
9 # Output files are in desired directory, see them e.g. by:
10 ls -lh Desktop/MyFile*
```



**Figure 4:** Import of output of `sondovac_part_a.sh` into Geneious for next processing (see page 5). Go to menu **File** (1) | **Import** (2) | **From file...**(3) and import output of `sondovac_part_a.sh`. You should see similar result as (4).

### 3.3 Geneious usage

Import output file of part A of the script (`sondovac_part_a.sh`): go to menu **File** | **Import** | **From File...** This file is named as: `*_blat_unique_transcripts-versus_genome_skim_data-no_missing_fin.fsa` (see Figure 4).

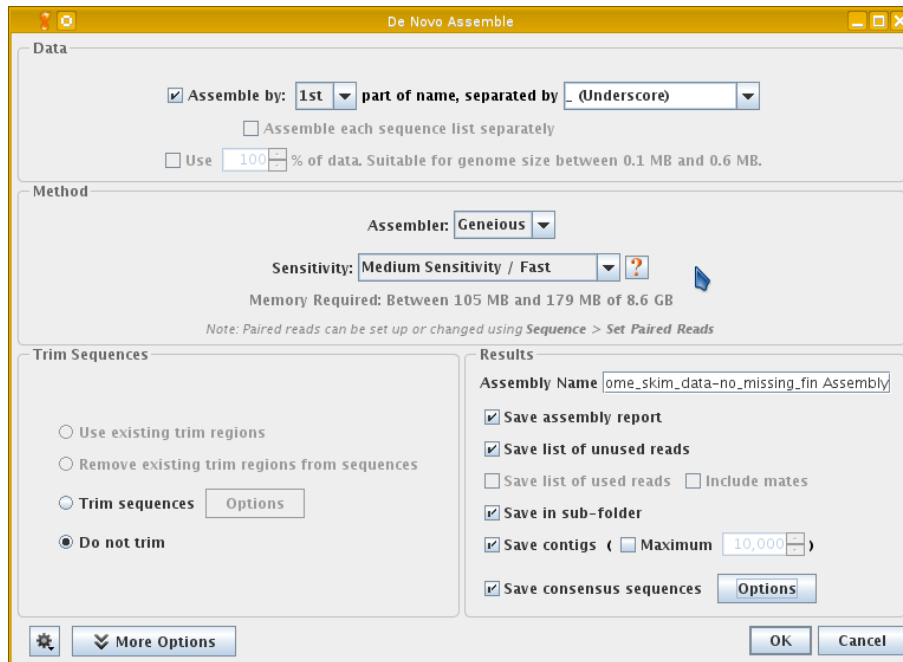
Select the file and go to menu **Tools** | **Align / Assemble** | **De Novo Assemble**. In **Data** frame select **Assemble by 1st (...)** **Underscore**. In **Method** frame select **Geneious Assembler** (if you don't have other assemblers, this option might be missing) and **Medium Sensitivity** / **Fast Sensitivity** (see Figure 5).

In **Results** frame check **Save assembly report**, **Save list of unused reads**, **Save in sub-folder**, **Save contigs** (do not check **Maximum**) and **Save consensus sequences**. Do not trim. Otherwise keep defaults. Run it. Geneious may warn about possible hanging because of big file. Do not use Geneious for other tasks during the assembly. Running may take long time (see Figure 5).

Select all resulting contigs (typically named **\* Contig #**) and export them (go to menu **File** | **Export** | **Selected Documents...**) as **Tab-separated table values (\*.tsv)**. Save following columns (Hold **Ctrl** key to mark more fields): **# Sequences**, **% Pairwise Identity**, **Description**, **Mean Coverage**, **Name** and **Sequence Length**. If this option would be inaccessible for you, export all columns (see Figure 6). Warning! Do not select and export **\* Consensus Sequences**, **\* Unused Reads** or **\* Report** – only the individual **\* contig #** files (see Figure 6).

Select items **Consensus Sequences** and **Unused Reads** and export them as one **FASTA**. Go to menu **File** | **Export** | **Selected Documents...** and choose **FASTA file type** (see Figure 7).

Use exported files from Geneious as input for part B of the script (`sondovac_part_b.sh`).



**Figure 5:** Settings of Geneious assembly as described in main text. It can take longer time to run it.

### 3.4 Record output of Sondovač

To record whole output of Sondovač script (regardless parameters used) use utility `tee`. It will produce plain text output with everything printed to the screen. It can be useful for reference or explorations is something went wrong. Use it as follows:

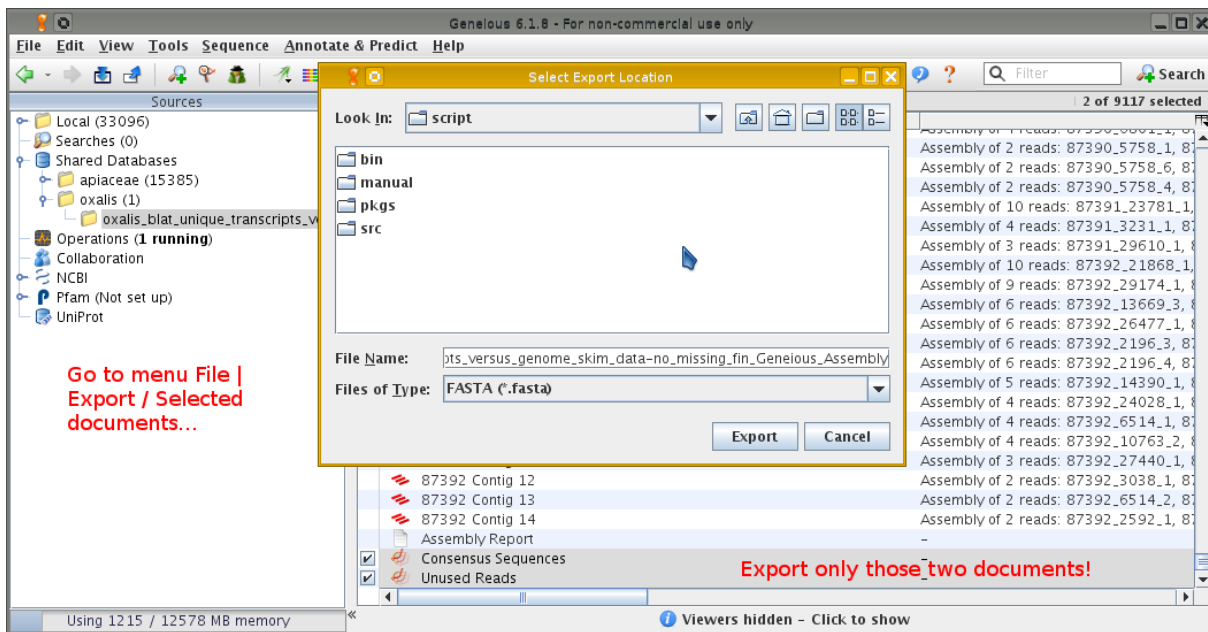
```
1 ./sondovac_part_a.sh | tee records.log
2 man tee # See more options how tee can record script's output
3 # "|" is a pipe passing output of 1st command as input for 2nd command
4 less records.log # See the record. Quit viewing by "Q"
5 rm records.log # Delete the log file
```

You can use any command line arguments, script will behave as usually. Plain text file `records.log` will then contain all its output. Unfortunately, `tee` usually wrongly records "invisible" characters – tabs and colorization used to highlight user messages in the script. If you see weird characters in `textttrecords.log` disturbing reading, use following commands:

```
1 # Assume output of Sondovač is name "records.log"
2 sed -i 's/.\[[[:digit:]]\{1,2\}m//g' records.log
3 # Explanation of regular expression (find pattern and replace by nothing):
4 # any character, [, one/two number(s), m (sequence defining text formatting)
5 sed -i 's/.(B.\[m//g' records.log
6 # Explanation of regular expression (find pattern and replace by nothing):
7 # any character, (, B, [, m (sequence defining text formatting)
8 # Escaping \[ \] is required to search specifically for brackets []
9 # (NOT searching for any character within [...] - there is no escaping)
10 # but \{...\} define number of occurrences of previous character(s)
```

Note for Mac OS X users: the regular expressions above require GNU `sed`, not version presented by default in Mac OS X. It is installed by Sondovač using Homebrew (see page 10), but to launch it you will probably must use command `gsed` instead of `sed`.





**Figure 7:** Select only documents **Consensus Sequences** and **Unused Reads** and export them as FASTA format (see also Figure 6).

## 4 Sample data

Together with the script, we provide the ZIP archive (1.8 GB) that contains exemplary input files for running the script: *Oxalis* genome skim data as well as the *Ricinus* cpDNA and mtDNA reference sequences. See <https://github.com/V-Z/sondovac/wiki/Sample-data> for download of sample data.

The package contains:

1. `input1_JHCN_Oxalis_corniculata_transcriptome_data-unique_transcripts.fa` – reduced data of file `JHCN_Oxalis_corniculata_transcriptome_data.fa` (only unique transcripts) kindly provided by Prof. Soltis (parameter `-f`). See below for information how to get full dataset.
2. `input2_Ricinus_communis_reference_plastid_genome.fsa` – cpDNA reference (parameter `-c`), GenBank reference number [NC\\_016736](#).
3. `input3_J12_Oxalis_obtusa_J12_genome_skim_data_R1.fastq` – paired-end genome skim data, file 1 (parameter `-t`).
4. `input4_J12_Oxalis_obtusa_J12_genome_skim_data_R2.fastq` – paired-end genome skim data, file 2 (parameter `-q`).
5. `input5_Ricinus_communis_reference_mitochondrial_genome.fasta` – mtDNA reference (parameter `-m`), GenBank reference number [NC\\_015141](#).

Transcriptome input file is unpublished data from G. K.-S. Wong et al. (hopefully it will be published soon). When the data became public, we will post them on [GitHub](#). Data can be now found under

- <http://www.onekp.com/>
- <http://www.onekp.com/samples/list.php>
- <http://www.onekp.com/samples/single.php?id=JHCN>

The transcriptome FASTA file used for the probe design is named JHCN-SOAPdenovo-Trans-assembly.dnas.out and can be found under JHCN/Assembly/JHCN-SOAPdenovo-Trans-translated/. Information about how to get access to data download is given in [Matasci et al. \(2014\)](#).

Explanation of command line parameters is at page [19](#).

## 5 Questions not covered here, reporting bugs and wishes

If you have any question or you encounter some problem, please, see <https://github.com/V-Z/sondovac/issues> and feel free to ask any question and/or express any wish. The authors will do their best to help you.

## 6 Changelog

List of changes in released versions of Sondovač.

### 6.1 Version 0.99 release candidate released 2015-12- (GIT)

- Fixed error with some input files for part B
- Finished colorization of command-line user interface (part B)

### 6.2 Version 0.95 beta released 2015-11-27

- Offer the possibility to choose between transcripts or genome skim sequences for further processing.
- Colorization of command-line user interface (incomplete).
- Added possibility to change -minIdentity parameter of BLAT in step 11, part B.
- Fixed problems with some transcriptome input files.
- Added possibility to set custom bait length.
- Added information about article in MER introducing Sondovač.

### 6.3 Version 0.9 beta released 2015-10-23

- Highly enhanced part B.
- Better handling of variable output from Geneious.
- Possibility to specify custom output files name.
- Full support for Linux distributions using DEB – Debian, Ubuntu, Linux Mint and derivatives.
- Enhanced documentation.
- Support for Mac OS X, package management using Homebrew.
- Support for RedHat based Linux distributions – Fedora, Centos and Scientific Linux and derivatives.
- Better compilation and installation of required software.
- For downloading automatically select if to use wget (preferred) or curl.
- Various fixes.

## 6.4 Version 0.8 alpha released 2015-10-09

- Usage of mitochondrial reference sequence is optional.
- Better formatting of script messages.
- Various fixes and enhancements.

## 6.5 Version 0.7 alpha released 2015-10-06

- Fixed reported problems with sed differences among Linux and Mac OS X.
- Added more exhaustive documentation.
- Various fixes and enhancements.

## 6.6 Version 0.6 alpha released 2015-08-10

- Fixed problems with some versions of output of Geneious.
- Better compilation and installation of required additional software packages.
- Various fixes and enhancements.

## 6.7 Version 0.5 alpha released 2015-07-24

- First public release, early alpha stage.

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## References

Srikar Chamala, Nicolás García, Grant T. Godden, Vivek Krishnakumar, Ingrid E. Jordon-Thaden, Riet De Smet, W. Brad Barbazuk, Douglas E. Soltis, and Pamela S. Soltis. Mark-erMiner 1.0: A New Application for Phylogenetic Marker Development Using Angiosperm Transcriptomes. *Applications in Plant Sciences*, 3(4):1400115, 2015. ISSN 2168-0450. doi: 10.3732/apps.1400115. URL <http://www.bioone.org/doi/10.3732/apps.1400115>. 4

- Filipe de Sousa, Yann J. K. Bertrand, Stephan Nylinder, Bengt Oxelman, Jonna S. Eriksson, and Bernard E. Pfeil. Phylogenetic properties of 50 nuclear loci in *Medicago* (Leguminosae) generated using multiplexed sequence capture and next-generation sequencing. *PloS one*, 9(10):e109704, 2014. ISSN 1932-6203. doi: 10.1371/journal.pone.0109704. URL <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0109704>. 4
- Brant C. Faircloth, John E. McCormack, Nicholas G. Crawford, Michael G. Harvey, Robb T. Brumfield, and Travis C. Glenn. Ultraconserved Elements Anchor Thousands of Genetic Markers Spanning Multiple Evolutionary Timescales. *Systematic Biology*, 61(5):717–726, 2012. ISSN 1063-5157. doi: 10.1093/sysbio/sys004. URL <http://sysbio.oxfordjournals.org/content/61/5/717.short>. 4
- Limin Fu, Beifang Niu, Zhengwei Zhu, Sitao Wu, and Weizhong Li. CD-HIT: Accelerated for clustering the next-generation sequencing data. *Bioinformatics*, 28(23):3150–3152, 2012. ISSN 13674803. doi: 10.1093/bioinformatics/bts565. URL <http://bioinformatics.oxfordjournals.org/content/28/23/3150.short>. 15
- Gordon and Hannon. FASTX-Toolkit. FASTQ/A short-reads pre-processing tools, 2010. URL [http://hannonlab.cshl.edu/fastx\\_toolkit/](http://hannonlab.cshl.edu/fastx_toolkit/). 15
- Corrinne E. Grover, Joseph P. Gallagher, Josef J. Jareczek, Justin T. Page, Joshua A. Udall, Michael A. Gore, and Jonathan F. Wendel. Re-evaluating the phylogeny of allopolyploid *Gossypium* L. *Molecular Phylogenetics and Evolution*, 92:45–52, 2015. ISSN 10557903. doi: 10.1016/j.ympev.2015.05.023. URL <http://www.sciencedirect.com/science/article/pii/S1055790315001669>. 4
- Shannon M. Hedtke, Matthew J. Morgan, David C. Cannatella, and David M. Hillis. Targeted Enrichment: Maximizing Orthologous Gene Comparisons across Deep Evolutionary Time. *PLoS ONE*, 8(7):1–10, 2013. ISSN 19326203. doi: 10.1371/journal.pone.0067908. URL <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0067908>. 4
- Karolina Heyduk, Dorset W. Trapnell, Craig F. Barrett, and Jim Leebens-Mack. Phylogenomic analyses of species relationships in the genus *Sabal* (Arecaceae) using targeted sequence capture. *Biological Journal of the Linnean Society*, 2015. URL <http://onlinelibrary.wiley.com/doi/10.1111/bij.12551/full>. 4
- Ying Huang, Beifang Niu, Ying Gao, Limin Fu, and Weizhong Li. CD-HIT Suite: a web server for clustering and comparing biological sequences. *Bioinformatics*, 26(5):680–682, 2010. ISSN 1367-4803. doi: 10.1093/bioinformatics/btq003. URL <http://bioinformatics.oxfordjournals.org/content/26/5/680>. 15
- Olivier Jeffroy, Henner Brinkmann, Frédéric Delsuc, and Hervé Philippe. Phylogenomics: the beginning of incongruence? *Trends in Genetics*, 22(4):225–231, 2006. ISSN 01689525. doi: 10.1016/j.tig.2006.02.003. URL <http://www.sciencedirect.com/science/article/pii/S0168952506000515>. 4
- Matthew Kearse, Richard Moir, Amy Wilson, Steven Stones-Havas, Matthew Cheung, Shane Sturrock, Simon Buxton, Alex Cooper, Sidney Markowitz, Chris Duran, Tobias Thierer, Bruce Asthon, Peter Meintjes, and Alexei J. Drummond. Geneious Basic: An integrated and extendable desktop software platform for the organization and analysis of sequence data. *Bioinformatics*, 28(12):1647–1649, April 2012. ISSN 1367-4803. doi: 10.1093/bioinformatics/bts199. URL <http://bioinformatics.oxfordjournals.org/content/28/12/1647>. 14, 16
- W. James Kent. BLAT — The BLAST -Like Alignment Tool. *Genome research*, 12:656–664, 2002. ISSN 1088-9051. doi: 10.1101/gr.229202. URL <http://genome.cshlp.org/content/12/4/656.short>. 15

- Ben Langmead and Steven L. Salzberg. Fast gapped-read alignment with Bowtie 2. *Nature Methods*, 9(4):357–359, April 2012. ISSN 1548-7091. doi: 10.1038/nmeth.1923. URL <http://www.nature.com/nmeth/journal/v9/n4/abs/nmeth.1923.html>. 15
- Heng Li. A statistical framework for SNP calling, mutation discovery, association mapping and population genetical parameter estimation from sequencing data. *Bioinformatics*, 27(21):2987–2993, 2011a. ISSN 1367-4803. doi: 10.1093/bioinformatics/btr509. URL <http://bioinformatics.oxfordjournals.org/content/27/21/2987>. 16
- Heng Li. Improving SNP discovery by base alignment quality. *Bioinformatics*, 27(8):1157–1158, 2011b. ISSN 1367-4803. doi: 10.1093/bioinformatics/btr076. URL <http://bioinformatics.oxfordjournals.org/content/27/8/1157>. 16
- Heng Li, Bob Handsaker, Alec Wysoker, Tim Fennell, Jue Ruan, Nils Homer, Gabor Marth, Goncalo Abecasis, Richard Durbin, and 1000 Genome Project Data Processing Subgroup. The Sequence Alignment/Map format and SAMtools. *Bioinformatics*, 25(16):2078–2079, 2009. ISSN 1367-4811. doi: 10.1093/bioinformatics/btp352. URL <http://bioinformatics.oxfordjournals.org/content/25/16/2078.full>. 16
- Weizhong Li and Adam Godzik. Cd-hit: A fast program for clustering and comparing large sets of protein or nucleotide sequences. *Bioinformatics*, 22(13):1658–1659, 2006. ISSN 13674803. doi: 10.1093/bioinformatics/btl158. URL <http://bioinformatics.oxfordjournals.org/content/22/13/1658.short>. 15
- Weizhong Li, Lukasz Jaroszewski, and Adam Godzik. Clustering of highly homologous sequences to reduce the size of large protein databases. *Bioinformatics (Oxford, England)*, 17(3):282–283, 2001. doi: 10.1093/bioinformatics/17.3.282. URL <http://bioinformatics.oxfordjournals.org/content/17/3/282.short>. 15
- Weizhong Li, Lukasz Jaroszewski, and Adam Godzik. Tolerating some redundancy significantly speeds up clustering of large protein databases. *Bioinformatics (Oxford, England)*, 18(1):77–82, 2002. ISSN 1367-4803. doi: 10.1093/bioinformatics/18.1.77. URL <http://bioinformatics.oxfordjournals.org/content/18/1/77.short>. 15
- Weizhong Li, Limin Fu, Beifang Niu, Sitao Wu, and John Wooley. Ultrafast clustering algorithms for metagenomic sequence analysis. *Briefings in Bioinformatics*, 13(6):656–668, 2012. ISSN 1467-5463. doi: 10.1093/bib/bbs035. URL <http://bib.oxfordjournals.org/content/13/6/656>. 15
- Tanja Magoč and Steven L. Salzberg. FLASH: fast length adjustment of short reads to improve genome assemblies. *Bioinformatics*, 27(21):2957–2963, 2011. ISSN 1367-4803. doi: 10.1093/bioinformatics/btr507. URL <http://bioinformatics.oxfordjournals.org/content/27/21/2957>. 15
- Jennifer R. Mandel, Rebecca B. Dikow, Vicki A. Funk, Rishi R. Masalia, S. Evan Staton, Alex Kozik, Richard W. Michelmore, Loren H. Rieseberg, and John M. Burke. A Target Enrichment Method for Gathering Phylogenetic Information from Hundreds of Loci: An Example from the Compositae. *Applications in Plant Sciences*, 2(2):1–6, feb 2014. ISSN 2168-0450. doi: 10.3732/apps.1300085. URL <http://www.bioone.org/doi/abs/10.3732/apps.1300085>. 4
- Jennifer R. Mandel, Rebecca B. Dikow, and Vicki A. Funk. Using phylogenomics to resolve mega-families: An example from Compositae. *Journal of Systematics and Evolution*, 53(5): 391–402, 2015. ISSN 16744918. doi: 10.1111/jse.12167. URL <http://onlinelibrary.wiley.com/doi/10.1111/jse.12167/full>. 4



- Naim Matasci, Ling-Hong Hung, Zhixiang Yan, Eric J. Carpenter, Norman J. Wickett, Siavash Mirarab, Nam Nguyen, Tandy Warnow, Saravanaraj Ayyampalayam, Michael Barker, J. Burleigh, Matthew A. Gitzendanner, Eric Wafula, Joshua P. Der, Claude W. DePamphilis, Béatrice Roure, Hervé Philippe, Brad R. Ruhfel, Nicholas W. Miles, Sean W. Graham, Sarah Mathews, Barbara Surek, Michael Melkonian, Douglas E. Soltis, Pamela S. Soltis, Carl Rothfels, Lisa Pokorny, Jonathan A. Shaw, Lisa DeGironimo, Dennis W. Stevenson, Juan Villarreal, Tao Chen, Toni M. Kutchan, Megan Rolf, Regina S. Baucom, Michael K. Deyholos, Ram Samudrala, Zhijian Tian, Xiaolei Wu, Xiao Sun, Yong Zhang, Jun Wang, Jim Leebens-Mack, and Gane Ka-Shu Wong. Data access for the 1,000 Plants (1KP) project. *GigaScience*, 3(1):17, 2014. ISSN 2047-217X. doi: 10.1186/2047-217X-3-17. URL <http://www.gigasciencejournal.com/content/3/1/17>. 28
- James A. Nicholls, R. Toby Pennington, Erik J. M. Koenen, Colin E. Hughes, Jack Hearn, Lynsey Bunnefeld, Kyle G. Dexter, Graham N. Stone, and Catherine A. Kidner. Using targeted enrichment of nuclear genes to increase phylogenetic resolution in the neotropical rain forest genus *Inga* (Leguminosae: Mimosoideae). *Frontiers in Plant Science*, 6(September):1–20, 2015. ISSN 1664-462X. doi: 10.3389/fpls.2015.00710. URL <http://journal.frontiersin.org/article/10.3389/fpls.2015.00710/abstract>. 4
- Beifang Niu, Limin Fu, Shulei Sun, and Weizhong Li. Artificial and natural duplicates in pyrosequencing reads of metagenomic data. *BMC bioinformatics*, 11:187, 2010. ISSN 1471-2105. doi: 10.1186/1471-2105-11-187. URL <http://www.biomedcentral.com/1471-2105/11/187/>. 15
- Matthew Parks, Richard Cronn, and Aaron Liston. Increasing phylogenetic resolution at low taxonomic levels using massively parallel sequencing of chloroplast genomes. *BMC Biology*, 7(1):84, 2009. ISSN 1741-7007. doi: 10.1186/1741-7007-7-84. URL <http://www.biomedcentral.com/1741-7007/7/84/>. 4
- Matthew Parks, Richard Cronn, and Aaron Liston. Separating the wheat from the chaff: mitigating the effects of noise in a plastome phylogenomic data set from *Pinus* L. (Pinaceae). *BMC evolutionary biology*, 12(1):100, jan 2012. ISSN 1471-2148. doi: 10.1186/1471-2148-12-100. URL <http://www.biomedcentral.com/1471-2148/12/100/>. 4
- Yohan Pillon, Jennifer Johansen, Tomoko Sakishima, Srikar Chamala, W. Brad Barbazuk, and Elizabeth A. Stacy. Primers for low-copy nuclear genes in *Metrosideros* and cross-amplification in *Myrtaceae*. *Applications in plant sciences*, 2(10):1400049, 2014. ISSN 2168-0450. doi: 10.3732/apps.1400049. URL <http://www.bioone.org/doi/abs/10.3732/apps.1400049>. 4
- R. Alexander Pyron. Post-molecular systematics and the future of phylogenetics. *Trends in Ecology & Evolution*, 30(7):384–389, 2015. ISSN 01695347. doi: 10.1016/j.tree.2015.04.016. URL <http://www.sciencedirect.com/science/article/pii/S0169534715001093>. 4
- Jeff Reneker, Eric Lyons, Gavic C. Conant, J. Chris Pires, Michael Freeling, Chi-Ren Shyu, and Dmitry Korkin. PNAS Plus: Long identical multispecies elements in plant and animal genomes. *Proceedings of the National Academy of Sciences*, 109(19):E1183–E1191, 2012. ISSN 0027-8424. doi: 10.1073/pnas.1121356109. URL <http://www.pnas.org/content/109/19/E1183.short>. 4
- Carl J. Rothfels, Anders Larsson, Fay-Wei Li, Erin M. Sigel, Layne Huiet, Dylan O. Burge, Markus Ruhsam, Sean W. Graham, Dennis W. Stevenson, Gane Ka-Shu Wong, Petra Korall, and Kathleen M. Pryer. Transcriptome-Mining for Single-Copy Nuclear Markers in Ferns. *PLoS ONE*, 8(10):e76957, 2013. ISSN 1932-6203. doi: 10.1371/journal.pone.0076957. URL <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0076957>. 4

- Roswitha Schmickl, Aaron Liston, Vojtěch Zeisek, Kenneth Oberlander, Kevin Weitemier, Shannon C.K. Straub, Richard C Cronn, Léanne L Dreyer, and Jan Suda. Phylogenetic marker development for target enrichment from transcriptome and genome skim data: the pipeline and its application in southern African Oxalis (Oxalidaceae). *Molecular Ecology Resources*, 2016. ISSN 1755098X. doi: 10.1111/1755-0998.12487. URL <http://onlinelibrary.wiley.com/doi/10.1111/1755-0998.12487/abstract>. 1, 3, 4, 16, 22
- Brian Tilston Smith, Michael G. Harvey, Brant C. Faircloth, Travis C. Glenn, and Robb T. Brumfield. Target Capture and Massively Parallel Sequencing of Ultraconserved Elements for Comparative Studies at Shallow Evolutionary Time Scales. *Systematic Biology*, 63(1):83–95, 2014. ISSN 1063-5157. doi: 10.1093/sysbio/syt061. URL <http://sysbio.oxfordjournals.org/content/63/1/83>. 4
- Jessica D. Stephens, Willie L. Rogers, Karolina Heyduk, Jennifer M. Cruse-Sanders, Ron O. Determann, Travis C. Glenn, and Russell L. Malmberg. Resolving phylogenetic relationships of the recently radiated carnivorous plant genus *Sarracenia* using target enrichment. *Molecular phylogenetics and evolution*, 85:76–87, 2015a. ISSN 1095-9513. doi: 10.1016/j.ympev.2015.01.015. URL <http://www.sciencedirect.com/science/article/pii/S1055790315000330>. 4
- Jessica D. Stephens, Willie L. Rogers, Chase M. Mason, Lisa A. Donovan, and Russell L. Malmberg. Species tree estimation of diploid *Helianthus* (Asteraceae) using target enrichment. *American Journal of Botany*, 102(6):910–920, 2015b. ISSN 0002-9122. doi: 10.3732/ajb.1500031. URL <https://www.amjbot.org/content/102/6/910.full>. 4
- Shannon C. K. Straub, Matthew Parks, Kevin Weitemier, Mark Fishbein, Richard C. Cronn, and Aaron Liston. Navigating the tip of the genomic iceberg: Next-generation sequencing for plant systematics. *American journal of botany*, 99(2):349–64, February 2012. ISSN 1537-2197. doi: 10.3732/ajb.1100335. URL <http://www.ncbi.nlm.nih.gov/pubmed/22174336>. 20
- Jeanne Tonnabel, Isabelle Olivieri, Agnès Mignot, Anthony Rebelo, Fabienne Justy, Sylvain Santoni, Stéphanie Caroli, Laure Sauné, Olivier Bouchez, and Emmanuel J P Douzery. Developing nuclear DNA phylogenetic markers in the angiosperm genus *Leucadendron* (Proteaceae): A next-generation sequencing transcriptomic approach. *Molecular Phylogenetics and Evolution*, 70(1):37–46, 2014. ISSN 10557903. doi: 10.1016/j.ympev.2013.07.027. URL <http://www.sciencedirect.com/science/article/pii/S1055790313003047>. 4
- Kevin Weitemier, Shannon C. K. Straub, Richard C. Cronn, Mark Fishbein, Roswitha Schmickl, Angela McDonnell, and Aaron Liston. Hyb-Seq: Combining target enrichment and genome skimming for plant phylogenomics. *Applications in Plant Sciences*, 2(9):1–7, 2014. doi: 10.3732/apps.1400042. URL <http://www.bioone.org/doi/full/10.3732/apps.1400042>. 4