```
> read("M5.txt")
> Help5( )
```

RecToSeq(INI,REC,N), GrowthC(INI,REC,K) , GrowthCe(REC)
LeslieMod(SUR,FER): e.g. LeslieMod([9/10,9/10],[0,1,1]);
LeslieMat(SUR,FER); e.g. LeslieMat([9/10,9/10],[0,1,1]); **(1)**

#0)

```
> eq := {6 a(n - 1) + a(n + 3) + 5 a(n + 1) = 0}
```

$$eq := \{6\,a(n-1)+a(n+3)+5\,a(n+1)=0\} \quad \textbf{(2)}$$

```
> subs(n = n - 3, eq);
```

$$\{6\,a(n-4)+a(n)+5\,a(n-2)=0\} \quad \textbf{(3)}$$

#Canonical form: a(n) = 0*a(n-1) - 5a(n-2) + 0*a(n-3) - 6a(n-4)

```
> RecToSeq([1, 2, 4, 11], [0, -5, 0, -6], 1000)[1000];
```

18180145897934968421192633539771659559011692513000811520173017916290300095791\ **(4)**
947742099251349107677679933500340055959624417148581612767396466425154660 61\
8131176283941650552170945484194399749328351304786759734718454695940190 4109\
745684403540309

#1)

```
> GrowthC([1, 2, 3, 4, 5, 6, 7, 8, 9, 10], [1, 1, 1, 1, 1, 1, 1, 1, 1, 1], 100)
```

1.999018633 **(5)**

```
> GrowthCe([1, 1, 1, 1, 1, 1, 1, 1, 1, 1])
```

1.999018633 **(6)**

#2)

```
> LeslieMod([99/100, 99/100, 99/100], [0, 1/2, 1/4, 0])
```

$$\left[0,\ \frac{99}{200},\ \frac{9801}{40000},\ 0\right] \quad \textbf{(7)}$$

```
> GrowthCe(%)
```

0.8795363925 **(8)**

```
> with(LinearAlgebra)
```

[*&x*, *Add*, *Adjoint*, *BackwardSubstitute*, *BandMatrix*, *Basis*, *BezoutMatrix*, *BidiagonalForm*, **(9)**
BilinearForm, *CARE*, *CharacteristicMatrix*, *CharacteristicPolynomial*, *Column*,
ColumnDimension, *ColumnOperation*, *ColumnSpace*, *CompanionMatrix*,
CompressedSparseForm, *ConditionNumber*, *ConstantMatrix*, *ConstantVector*, *Copy*,
CreatePermutation, *CrossProduct*, *DARE*, *DeleteColumn*, *DeleteRow*, *Determinant*,
Diagonal, *DiagonalMatrix*, *Dimension*, *Dimensions*, *DotProduct*, *EigenConditionNumbers*,
Eigenvalues, *Eigenvectors*, *Equal*, *ForwardSubstitute*, *FrobeniusForm*,
FromCompressedSparseForm, *FromSplitForm*, *GaussianElimination*, *GenerateEquations*,
GenerateMatrix, *Generic*, *GetResultDataType*, *GetResultShape*, *GivensRotationMatrix*,
GramSchmidt, *HankelMatrix*, *HermiteForm*, *HermitianTranspose*, *HessenbergForm*,
HilbertMatrix, *HouseholderMatrix*, *IdentityMatrix*, *IntersectionBasis*, *IsDefinite*,
IsOrthogonal, *IsSimilar*, *IsUnitary*, *JordanBlockMatrix*, *JordanForm*, *KroneckerProduct*,
LA_Main, *LUDecomposition*, *LeastSquares*, *LinearSolve*, *LyapunovSolve*, *Map*, *Map2*,
MatrixAdd, *MatrixExponential*, *MatrixFunction*, *MatrixInverse*, *MatrixMatrixMultiply*,

MatrixNorm, *MatrixPower*, *MatrixScalarMultiply*, *MatrixVectorMultiply*, *MinimalPolynomial*, *Minor*, *Modular*, *Multiply*, *NoUserValue*, *Norm*, *Normalize*, *NullSpace*, *OuterProductMatrix*, *Permanent*, *Pivot*, *PopovForm*, *ProjectionMatrix*, *QRDecomposition*, *RandomMatrix*, *RandomVector*, *Rank*, *RationalCanonicalForm*, *ReducedRowEchelonForm*, *Row*, *RowDimension*, *RowOperation*, *RowSpace*, *ScalarMatrix*, *ScalarMultiply*, *ScalarVector*, *SchurForm*, *SingularValues*, *SmithForm*, *SplitForm*, *StronglyConnectedBlocks*, *SubMatrix*, *SubVector*, *SumBasis*, *SylvesterMatrix*, *SylvesterSolve*, *ToeplitzMatrix*, *Trace*, *Transpose*, *TridiagonalForm*, *UnitVector*, *VandermondeMatrix*, *VectorAdd*, *VectorAngle*, *VectorMatrixMultiply*, *VectorNorm*, *VectorScalarMultiply*, *ZeroMatrix*, *ZeroVector*, *Zip*]

> $LeslieMat\left(\left[\frac{99}{100}, \frac{99}{100}, \frac{99}{100}\right], \left[0, \frac{1}{2}, \frac{1}{4}, 0\right]\right)$

$$\begin{bmatrix} 0 & \frac{1}{2} & \frac{1}{4} & 0 \\ \frac{99}{100} & 0 & 0 & 0 \\ 0 & \frac{99}{100} & 0 & 0 \\ 0 & 0 & \frac{99}{100} & 0 \end{bmatrix} \quad \textbf{(10)}$$

> $Eigenvalues(\%)$

$$\left[\left[\left[0\right], \right.\right. \quad \textbf{(11)}$$

$$\left[\frac{\left(980100 + 3300\sqrt{61809}\right)^{1/3}}{200} + \frac{33}{\left(980100 + 3300\sqrt{61809}\right)^{1/3}}\right],$$

$$\left[-\frac{\left(980100 + 3300\sqrt{61809}\right)^{1/3}}{400} - \frac{33}{2\left(980100 + 3300\sqrt{61809}\right)^{1/3}}\right.$$

$$\left.\left. + \frac{3\,I\sqrt{3}\left(\frac{\left(980100 + 3300\sqrt{61809}\right)^{1/3}}{30} - \frac{220}{\left(980100 + 3300\sqrt{61809}\right)^{1/3}}\right)}{40}\right],$$

$$\left[-\frac{\left(980100+3300\sqrt{61809}\right)^{1/3}}{400} - \frac{33}{2\left(980100+3300\sqrt{61809}\right)^{1/3}} - \frac{3\,I\sqrt{3}\left(\frac{\left(980100+3300\sqrt{61809}\right)^{1/3}}{30} - \frac{220}{\left(980100+3300\sqrt{61809}\right)^{1/3}}\right)}{40} \right]$$

```
> evalf( (980100+3300*sqrt(61809))^(1/3)/200 + 33/(980100+3300*sqrt(61809))^(1/3) )
```

$$0.8795363925 \quad \textbf{(12)}$$

```
> #0.8795363925 is the growth rate as seen from both methods.
```

#3)

```
> #Equation for growth rate of salmon: s(t)= 0.16S(t − 4) + 0.41S(t − 5)
```

REC = [0,0,0,0.16,0.41]

```
> GrowthCe([0, 0, 0, 0.16, 0.41])
```

$$0.8879729192 \quad \textbf{(13)}$$

#4)

gamma = number of seeds produced per plant in August; alpha = fraction of one-year-old seeds that germinate in May; beta = fraction of two-year-old seeds that germinate in May; sigma= fraction of seeds that survive a given winter.

```
> PlantGseq := proc(alpha, beta, gamma, sigma, INI, K)
    REC := [alpha·sigma·gamma, beta·sigma^2(1 − alpha)·gamma]
    if not (type(INI, list) and type(REC, list) and nops(INI) = nops(REC) and type(N, integer)
        and N ≥ nops(INI)) then
    print(`bad input`):
    RETURN(FAIL):
    fi:
    end
Error, unable to parse
PlantGseq := proc(α, β, γ, σ, INI, K) REC := [α·σ·γ, β·σ^2(1 − α)·γ] if not (type(INI, list) and type(REC, list)
```

#5)

```
> PlantGseq := proc(alpha, beta, gamma, sigma)
    GrowthCe([alpha·sigma·gamma, beta·sigma^2(1 − alpha)·gamma])
    end
```

```
PlantGseq := proc(alpha, beta, gamma, sigma)
    GrowthCe([alpha * sigma * gamma, beta * sigma(1 − alpha)^2 * gamma])
end proc
```

(14)

```
> PlantGseq(0.5, 0.25, 2, 0.8)
```

$$1.092820323 \quad \textbf{(15)}$$

```
> PlantGseq(0.99, 0.99, 100, 0.99)
```

$$98.99019706 \quad \textbf{(16)}$$

#using alpha, beta and sigma values close to 1 and a large gamma value will lead to population

explosion

```
> PlantGseq(0.01, 0.01, 2, 0.01)
```

$$0.001517744688 \quad \textbf{(17)}$$

#using alpha, beta and sigma values close to 0 and a small gamma value will lead to population extinction

```
> PlantGseq(0.5, 0.5, 1, 0.5)
```

$$0.5000000000 \quad \textbf{(18)}$$

#using alpha, beta and sigma values close to 0.5 will lead to population stability

```
>
```