

# **MDIA5004**

A YX]U'UbX'Di V`]WF Y`Uh]cbg

HYfa "Hk c" ## "&\$&\$

## 7ci fgY'Cj Yfj ]Yk

#### GHJZZ7cbHJWh8YHJ]`g

#### 7cbj Ybcfg

B Ua Y	9a U]`	5j U]`UV]`]lm	@cWUh]cb	D\cbY
A]WXUY`?Ybh		, ,	B 5	B 5
		gYhk]h\ghXYbhg"		

#### GWkcc~7cbhJWh~abZcfa Uh]cb

GVXcc``cZhY`5fhg`UbX`AYX]U

Fcca ' %&ž@YjY`' žFcVYfhK YVghYf6i]`X]b[fl %(Ł

D\cbY.'f\$&E'-',)'(,)\*

9a U]` gUa 4 i bgk "YXi "Ui

K YVq]hY. k k k "Ufhq"i bak "YXi "Ui #qUa

 $\label{eq:hamiltonian} $$HY'GWKcc``cZhY'5ftg'UbX'AYX]U'kci`X``]_Y'hc'FYgdYWM\cong \cong m5W_bck`YX[Y'h\Y'HfUX]hjcbU``7ighcX]Ubgžh\Y'6YXY[U'`fPYbg]b[hcb'WJadigŁž'; UX][U'`fP]hmUbX'5fh\/'8Yg][b'7UadigYgŁ'UbX'h\Y'B[ibbUkU`dYcd'Y'fbighfU`]Ub'8YZYbW': cf\W'5\WJXYam]b'7UbVYffUŁ'cZh\Y'`UbXg'k\YfY'YUW\'WJadig'cZIBGK']g`c\WJhYX''$ 

### 7ci fgY 8YHJ] g

#### 7 fYX]hDc]bhg \*

#### Gi a a UfmcZh\Y 7ci fgY

H\]g`Wci fgY`]bHfcXi WYgʻghi XYbhgʻhcʻdi V`]WfY`UhJcbgʻk f]hJb[ 'UbX'a UbU[ Ya YbhUbX`XYj Y`cdgʻh\Y]f i bXYfghUbX]b[ 'cZdi V`]WfY`UhJcbgʻ]bʻh\Yʻ5i ghfU`]Ubʻa YX]UʻYbj ]fcba YbhʻGhi XYbhgʻk ]```YUfbʻh\YʻVUg]WgʻcZ k f]hJb[ 'Uʻa YX]UʻfYYUgYža UbU[ ]b[ 'UʻdfYggʻWcbZffYbWrUbX`XYU`]b[ 'k ]h\`a YX]UʻYbei ]f]Yg"'H\Y`k f]hJb[ Wca dcbYbhcZh\Y`Wci fgY`k ]```]bWi XY`k f]hJb[ 'Zcfʻh\Y`]bhYfbYhžgdYYW\Ygždi V`]WUhJcbgžWJa dU][ bgžfYdcftg UbX`Wf]g]gʻWca a i b]WUhJcbg"'5gʻk Y```Ugʻ`YUfb]b[ 'hc`k f]hY`UWfcggʻUʻfUb[ YʻcZ[ YbfYgžghi XYbhgʻk ]```YUfb`hc k f]hY`ZcfʻUʻgY`YWhX`Ui X]YbW'"'H\]gʻWci fgY`k ]```Uʻgc`Wcj Yfʻh\Y`k Umgʻh\UhbYk 'a YX]UʻhYW\bc`c[ ]Yg ]bZi YbWrʻa YX]UʻUbX`di V`]WfY`UhJcbg"'Ghi XYbhgʻk ]```UYʻhUi [ \hihYW\b]ei YgʻZcfʻi g]b[ 'h\YgY`hYW\bc`c[ ]YgʻZcf a YX]UʻUbX'di V`]WfY`UhJcbgʻdi fdcgYg"'Ghi XYbhgʻk ]```Uʻgc``YUfbʻh\Y`dfcZYgg]cbU``Wcbj YbhJcbgʻUbX`Yb[ U[ Y k ]h\`h\Y`Yh\]WD``UbX`Y[ U``]ggi YgʻUggcWJUhYX`k ]h\`di V`]WfY`UhJcbg''

#### 7 ci fgY @YUfb]b[ Ci hWca Yg

%" K f]hY 'U'dfYgg'fY`YUgY 'UbX'U'`YhhYf'hc'h\Y'YX]hcf#cd]b]cb'd]YWV &" C f[ Ub]qY'U'a YX]U'WcbZYfYbWV

' " 8Yj Y`cd`UbX`]a d`Ya YbhU`a YX]U`fY`Uh]cbg`WUa dU][ b`k cf\_]b[ ']b`U`[ fci d

("K flhy a YX]U a Uhyflu g Zcf U a YX]U fy Uhcbg WJa du][b

) "8 Ya cbqlfUlY 'Ub'i bXYfqlUbX]b[ 'cZh\YcfYh]WU``ZfUa Yk cf\_g'fY`Yj Ubhlc'a YX]U'UbX'di V`]WfY`Uh]cbq

#### HYUWX]b[ GhfUhY[]Yg

H\]g`Wci fgY`k ]```VY`Hui [\hzJ\W`hc`zJ\W`]b`U``Y\Wi fY`h\Y\UffY`Ybj ]fcba Ybh'Vi hih\YfY`k ]```VY`U`gffcb[
Ya d\Ug]g`cb`Yb\Wci fU[]b[`ghi XYbhdUff]\\]d\Uffcb`]b`h\Y`dfc\W`gg`cZ`YUfb]b["`Ghi XYbhg`k ]```VY`U\\f]j Y`m
Yb[U[YX`]b`gc`j ]b[`dfcV`Ya g`dcgYX`Vmh\Y``Y\Wi fYf''Ghi XYbh`YUfb]b[`k ]```VY`Yb\Ub\WX`Vmh\Y`i gY`cZ\\UgY
ghi X]Yg`UbX`Vm[fci d`k cf\_']b`k\]\\ ghi XYbhg`k ]```VY`Ug\_YX`hc`dfcXi \W`a YX]U`UbX`di V`]\\fY`Uf]cbg
a UhYf]\U`q`UbX`\Wa d\U][ bq`Zcf`U`fYU``\\]Ybh'

 $H\Y'WcbhYbhcZh\]g'WcifgY'UbX']hg'hYUWX]b['UddfcUWX']g'XYg][bYX'hc'YbUV'Y'ghiXYbhg'hc'XYjY`cd'dUfh]W'UfWcaaib]WUh]cbg'g_]``g'h\Uhk]f'Yb\UbW'h\Y]f'dfUWhW'UbX'kcf_']b'h\Y'Z]Y`X'cZaYX]U'UbX'diV']WfY`UhJcbg'' <math display="block"> \pm ifYZYWfg'amdcg]h]cb'h\Uhh\Y]f'dfUWhW'k]hYbb'hY'Z]Y`X'k]``fYei]fY'UXjUbWXX``YjY`g'cZWcaaib]WUh]cb'hcYbUV'Y'cb[c]b['XYjY`cdaYbh'$ 

### 5ggYgga Ybh

#### 5ggYgga Ybh'HUg\_g'

5ggYgga Ybh'tUg_	K Y][ \h	8iY'8UhY	Gh XYbh@YUfb]b[ Ci hWca Yg 5ggYggYX
@YMYfhchhY9X]hcfcf Cd]b]cbD]YWY	')।	&*#\$*#&\$&\$^\$).((*DA	%Ž)
A YX]U'd`Ub'Zcf'Bcb!DfcZ h Cf[Ub]gUh]cb'	' \$1	%+#\$+#&\$&\$^\$).(+*DA	&Z Ž)
A YX]U'F Y`YUgY'	')।	\$+#\$, #&\$&\$`\$).(, 'DA	( ž)

#### 5ggYgga Ybh'8YhJ]`g

5ggYgga Ybh% @YhYfhc h\Y 9X]hcfcfCd]b]cbD]YW

GhUfhXUhY. Bch5dd`]WUV`Y

@Yb[ h\. GYY gm`UVi g"

8YHJ]`g.

@YthYf'tc'th\Y'YX]tcf'f&\$\$'k cfXgŁ''Ž'fUt]cbU'Y'f) \$\$!, \$\$'k cfXgŁ'CF'cd]b]cb'd]YVW'f] \$\$'k cfXgŁ'Ž'fUt]cbU'Y f) \$\$!, \$\$'k cfXgŁ''

K f]hhYb ZYYXVUW\_'k ]``'VY dfcj ]XYX VmhYUWX]b[ 'ghUZZ'

Gi Va ]gg]cb bchYg.GYY gm`UVi g Zcf XYhU]`g"

5ggYgga Ybh'& 'A YX]U'd`Ub 'Zcf'Bcb!DfcZ]h'Cf[ Ub]gUh]cb

GhUfh'XUhY.

8 YW] g.

; fci d'5ggYgga YbhA YX]U'D`Ub'ZcfBcb!DfcZhCf[Ub]gUh]cb'f%) \$\$'k cfXgŁ"; fci dg'k]``hmd]WU``m'Wcbg]ghcZ' 'hc') 'gh XYbhg"'H\]g']g'h\Y'Z]bU``UggYgga YbhHUg\_"

5XX]h]cbU`XYhU]`g.

GYY'gm`UVi g'Zcf'XYhJ]`g"'

5ggYgga Ybh' . A YX]U F Y`YUgY

GhUfh'XUhY.

#### 8YHJ]`g.

 $A\ YX]U\ fY\ YUgY\ fl\ \$\$\ k\ cfXgŁ\ \check{Z}\ fUh]cbU\ Y\ fl)\ \$\$!\ ,\ \$\$\ k\ cfXgŁ\ ''$ 

 $\label{eq:Karlinder} K \ f] \hspace{-0.1cm} \text{MY b } \hspace{-0.1cm} \text{ZYYXVUW} \hspace{-0.1cm} \hspace{-0.1cm} \text{`k } \hspace{-0.1cm} \text{)} \hspace{-0.1cm} \text{```VY } \hspace{-0.1cm} \text{dfcj } \hspace{-0.1cm} \text{]XYX } \hspace{-0.1cm} \text{Vm} \hspace{-0.1cm} \text{MY UVW } \hspace{-0.1cm} \text{]b} \hspace{-0.1cm} \hspace{-0.1cm} \text{[} \hspace{-0.1cm} \hspace{-0.1cm} \text{[} \hspace{-0.1cm} \text{]} \text{b} \hspace{-0.1cm} \text{[} \hspace{-0.1cm} \text{$ 

#### 5XX]h]cbU`XYhJ]`g.

GYY 'gm`UVi g'Zcf'XYHJ]`g"'

Fygci fWyg

DfYgWf]VYX F Ygci fWYg

GYY'h\Y'gm`UVi g'cb'AccX`Y'Zcf'Wcad`YhY'XYhU]`g"

FYWca a YbXYX FYgci fWYg

7 ci fgY '9j U`i Uh]cb 'UbX '8Yj Y`cda Ybh

# Gi Va ]gg]cb cZ5ggYgga YbhHUg\_g Hi fb]h]b Gi Va ]gg]cb

-Zmci 'YbWci bhYf'U'dfcV`Ya 'k \Yb'UhhYa dh]b[ 'hc'gi Va ]hmci f'Ugg][ ba Ybhh\fci [ \'Hi fb]h]bž'd`YUgY hY`Yd\cbY'9I hYfbU``Gi ddcfhcb'-',)'''' %cf'Ya U]`'h\Ya 'cb'YI hYfbU`hY`hgi ddcfh4 i bgk "YXi "Ui '"'Gi ddcfh

## 5 WUXYa ]W<cbYghmUbX D`U[]Uf]ga

D`U[]Uf]ga `]g`i g]b[ 'h\Y`k cfXg`cf`]XYUg`cZch\Yfg`UbX`dfYgYbh]b[ 'h\Ya `Ug`mci f`ck b"`±hWJb`hU\_Y`a Ubm Zcfa gžZfca `XY`]VYfUhY`W\YUh]b[ 'hc`UWW]XYbhJ``mWcdm]b[ 'Zfca `U`gci fWY`k ]h\ci hUW\_bck `YX[ Ya Ybh'

IBGK [fcidg'd'U[]Uf]ga ]bhc'h\Y'Zc``ck]b[ 'WUhY[cf]Yg.

 $7 \text{ cdm}b[...i g]b[...h\Y.gUa Y.cf.j Yfmig]a] \Uf'k cfXg'hc'h\Y.cf][]bU''hYl h'cf']XYU'k]h\ci h'U\V_bck `YX[]b[...h\Y.cf][]bU''hYl h'cf']XYU'k]h'cf']$ 

- i bXYfgfUbX mci f'f][\hg'UbX'fYgdcbg]V]`]hJYg'Ug'U'gh XYbhUhl BGK
- VY`Uk UfY`cZd`U[]Uf]ga ž`Wcdmf][\hzil BGK `Gh XYbh7cXY`cZ7cbXi WhUbX`5VWWdhUv`Y`I gY`cZ I BGK `=\forall H`F Ygci f\W\g`Dc`]\wh
- VY 'Uk UfY 'cZh\Y 'ghUbXUfXg 'cZVY\Uj ]ci f'Yl dYWYX 'cZYj YfmcbY ']b 'h\Y 'l BGK 'Wca a i b]hm
- `cWUHY 'gYfj ]WYg'UbX `]bZcfa UH]cb'UVci hI BGK 'UbX'I BGK '@]VfUfm

Gca Y'cZh\YgY'UfYUg'k]``VY'ZJa]`]Uf'hc'mci ž'ch\Yfg'k]``VY'bYk"'; U]b]b['U'gc`]X'i bXYfgHJbX]b['cZU``h\YfY`UhYX'UgdYWng'cZ9@+69'k]``\Y`d'mci 'a U\_Y'h\Y'a cghicZmci f'ghi X]Yg'UhI BGK "'\\hd.##qi VYWfi |XYg"`]VfUfm'i bqk "YXi "Ui #\`]qY#JVci hY`]qY